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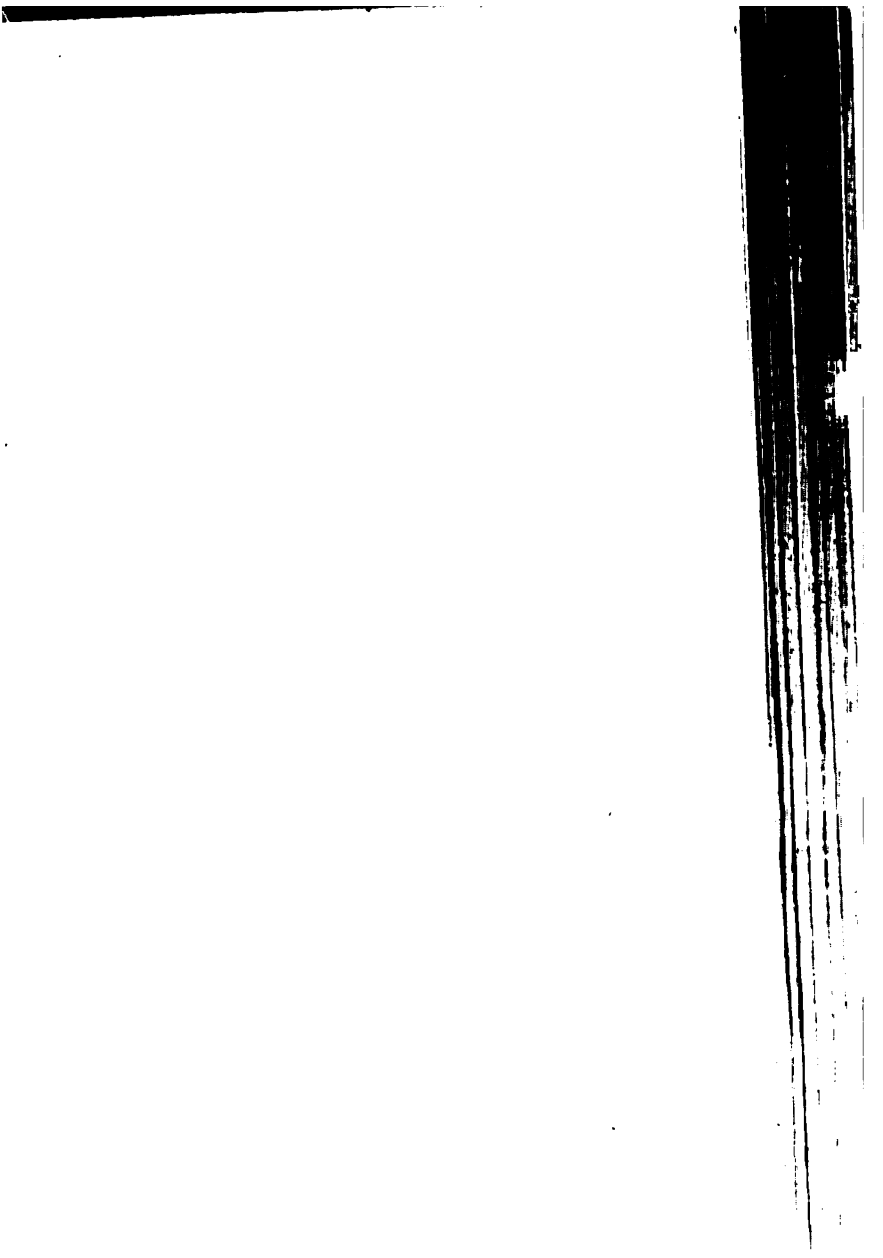

MOTOR CARS

AND THE APPLICATION OF

MECHANICAL POWER TO ROAD VEHICLES

BY

RHYS JENKINS

Memb. Inst. Mech. Eng.

THE FIRST STEAM CARRIAGE (C. 1771)

With 100 Illustrations

London
T. Fisher Unwin
New York

A ROYAL AUTOMOBILE.

(PORTRAIT OF HIS MAJESTY THE KING SEATED IN THE HONOURABLE
J. SCOTT MONTAGU'S CAR.)

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PREFACE

THE application of mechanical power to the propulsion of road vehicles is a subject which is now receiving a considerable amount of public attention. Interest in the matter is steadily growing, and there can be no doubt that the motor car has been perfected to an extent that fully entitles it to be regarded as a practical working machine, and we may look forward with certainty to an immense extension in its use during the next few years. In France the manufacture of motor cars has taken rank as an industry of first-rate importance, and we have every reason to hope that it will do the like in this country. That it has not already done so must be attributed to restrictive legislation but lately removed.

Although it is only of late that it has attracted any large amount of public interest, the subject is one which has engaged the attention of engineers and inventors for a very long period of time. The difficulties encountered in constructing a self-propelling vehicle for use on ordinary roads are of a nature not easily overcome, and the record of the attempts made to surmount them which is presented in this book forms a curious and instructive chapter in the history of invention.

As long ago as the thirteenth century Friar Bacon predicted that "it will be possible to construct chariots so that without animals they may be moved with incalculable speed." The modern racing motor car would probably fully satisfy Friar Bacon's ideas in regard to an incalculable speed, so that now, after a long interval, it may be said that his prediction has been realised.

Commencing with the mechanical and sailing carriages of the seventeenth century, the development of the application of

mechanical power to road vehicles has been traced up to the year 1896, when the subject had arrived at the rank of one of public importance. In doing this it has been essayed to show the dependence of this development upon that of the highways, upon the advance of the constructive arts, and upon the demands of the public for increased facilities for travelling. Chapters II., III., IV. and V. are based upon a series of articles contributed to *The Antiquary* in 1896. The historical treatment of the matter takes up, roughly-speaking, the first half of the book. The second half is devoted to the motor vehicles as they now exist and mainly to passenger vehicles and cycles, but it also includes a brief chapter on such motor wagons for the transport of goods as come within the scope of the Locomotives Act of 1896.

It has been deemed advisable to concentrate attention upon the petrol car and to deal but briefly with the steam and electric cars, not that these are less interesting, but because, judged by the numbers in use, they are comparatively less important. Every effort has been made to give such accounts of the cars dealt with as are correct at the time of going to press.

The number of distinct makes of motor vehicles before the public to-day is so great that, even if it were desirable, it would be impossible within the limits of such a work as this to deal with them all. Certain well-known and typical vehicles—British, Continental and American—are discussed fully, and a number of others are more briefly described in reference to such typical vehicles.

The subject in its modern aspect is necessarily to a certain extent technical; but, perhaps in consequence of the difficulties which have been encountered in the production of a satisfactory motor vehicle, there is a tendency to over-estimate the complexity of the machine. The difficulties have been, however, mainly in the selection and adaptation of the most suitable machinery for the work of the road. As a matter of fact, the mechanism of the motor car is, comparatively speaking,

simple, and it is hoped that the construction and action of the machines discussed will be found perfectly clear by the general reader, to whom primarily this work is addressed. Fuller information of a technical nature will be found in Mr W. Worby Beaumont's *Motor Vehicles and Motors*. The driving and management of motor cars has not been touched upon here; it has recently been fully dealt with by experts in the Badminton Volume on *Motors and Motor Driving*.

The author has to express his thanks to the Daimler, Wolseley and other firms whose productions are described for information, drawings, and the loan of blocks. For the section on Petrol he is indebted to Mr George T. Holloway, F.I.C., F.C.S.

R. J.

LONDON. *October* 1902.

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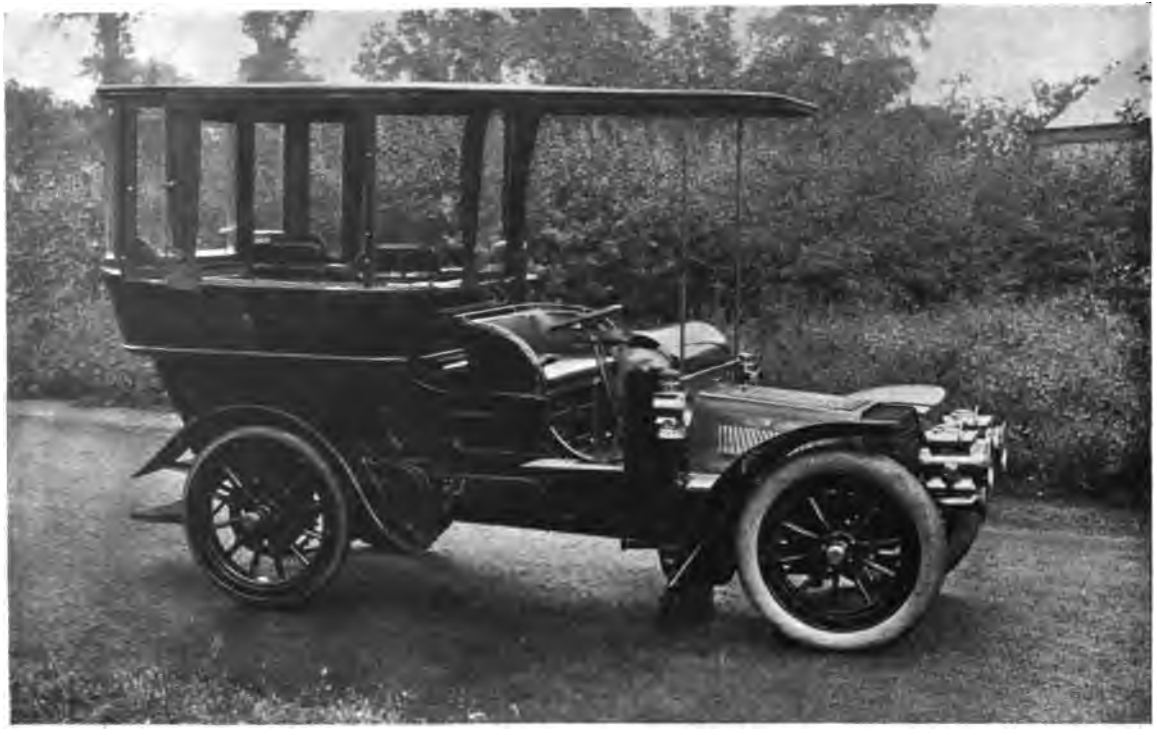


THE KING'S TWENTY-TWO HORSE-POWER DAIMLER MOTOR CARRIAGE, 1902.

MOTOR CARS

CHAPTER I

INTRODUCTION

It is almost superfluous to say that the motor car has now firmly established itself in our social economy, and that "motoring" is making rapid advance in all parts of the country; the evidence is before us everywhere. Nor can there be any question as to the progress which has been made during the last few years in the mechanical construction of the car. The most recent productions of all the leading makers are really serviceable machines, comfortable for the occupants—when run at reasonable speeds—under complete control, easily manipulated, capable of making long runs without breakdown, and they promise to be fairly durable; but it must be remembered that the motor car, like other machines, and as far as that goes like the horse as well, requires to be properly handled and cared for in order to secure good results.

Of the extent to which the motor car movement has grown one can form but a general idea; it is impossible to adduce any precise figures as to the number of cars in use. Our own manufacturers, although handicapped by the five years' delay imposed upon them by our prohibitive laws, make a considerable number of carriages; while, in addition to importations from America, Germany and

Belgium, France alone sent us, during the first six months of the year 1902, motor cars and accessories to the value of over £300,000. The motor car industry has indeed become one of great importance in that country, and thousands of workmen are engaged in it; our Consul-General at Paris states that after the Paris-Berlin motor car race the French makers received orders to the value of £4,320,000. This seems to indicate that motor racing has been of value for advertising purposes; perhaps also the building of racing cars has afforded greater facilities to the makers for the working out of the most appropriate constructions than would have been the case with touring or business vehicles. Otherwise one cannot but think that excessive speeds—and speeds of over eighty miles an hour have been reached—however well they may show what the maker can produce and how skilfully the driver can manipulate his machine, are not conducive to the progress of the motor car in the public estimation.

This leads us to the consideration of the present agitation for the removal of the speed limit now imposed by law in this country. Doubtless the limit of twelve miles per hour is too low for the open road, and doubtless also a skilful driver has such a complete control of a modern high-class machine as to be able to avert any possible accident even when running two or three times as fast, but it is to be borne in mind that all drivers are not skilful, nor are all machines well-made. Further, the question presents itself not merely as one of avoiding actual bodily damage to the foot-passenger. The convenience, and perhaps we may say the prejudices, of the general public have to be kept in view. The pedestrian has been accustomed to vehicular traffic moving at a speed no higher than that of a pair of fast-stepping horses; it is not unnatural, therefore, that a—to him—new and untried machine moving at a high velocity should give rise to a feeling of discomfort and alarm. Lady Jeune, an ardent advocate of the motor car, stated recently that in France

the number of motor cars has so increased, and the pace at which they travel is so rapid, that no one uses the main roads if he can avoid it. This is not a desirable state of affairs, nor is it one that can possibly be allowed to continue. It behoves those who have at heart the real advancement of the motor car movement to endeavour to accustom the public to increased speeds by gradual stages.

Whether the limit should be raised, or whether it should be abolished altogether, is of course a matter for discussion; much is to be said in favour of the latter course, but clearly it involves some form of official control of the fitness of the cars as well as that of their drivers. It is impossible even for the automobilist to contemplate with any degree of equanimity the idea of the irresponsible motor scorcher careering along the public highways upon a rickety machine.

Although it has been stated that really serviceable machines are now to be obtained, it is far from being suggested that anything approaching to perfection has yet been produced; improvements will continue to follow each other in quick succession for some time, and then a stage will be reached at which further advance will become more and more difficult; but these improvements can be arrived at only as the results of practical experience in the working of the machines, and will depend to a large extent upon the encouragement given by the public to the industry. It is indeed idle to look for absolute perfection in any product of human ingenuity. We have had the locomotive and the steamship with us as practical successes for many years, yet in both improvement follows improvement and no one thinks of finality; but in spite of defects these machines have been of incalculable service in the world, and this we take it is the position of the motor car at the present day; it is obviously not a perfect machine, but its defects are not such as to prevent it from being used to great advantage by the public, and this is true not

only of the pleasure carriage but also of the cycle and the lorry and van.

The problem of adapting mechanical power to road vehicles, in spite of its seeming simplicity, is really one of considerable difficulty. The designer has not only to produce a motor and gearing which will work without discomfort or annoyance to the occupants of the vehicle and the general public, but, what is far more difficult, he has to produce a machine which will work successfully upon a common road. Given such a surface as that of a railway to run upon and the problem would have been solved long since. The track and the wheels of the vehicle are really two elements in a single mechanical combination; the railway engineer has control of both, and is in position to adapt the one to suit the other; if he finds, from the necessities of growing traffic, or the demands for higher speeds, that more powerful, and therefore heavier engines are required, he can adapt his track to correspond to the increased load. The motor car engineer, on the other hand, has no such control over the track upon which his productions are to work; he has to build his machines to withstand inequalities of surface, which tend to jar them to pieces, as well as to climb steep gradients. Both these add to the power required for propulsion and thus to the weight of the motor and gearing; this again necessitates additional weight in the frame and wheels, and thus additional engine power, and so it goes on. Traction engines are notoriously heavy and cumbrous machines, but we may rest assured that they have not become so without due cause; their makers have been compelled by repeated breakages to continue strengthening and thereby increasing the weight of the parts; the proportions adopted are, in short, the result of costly experience as to what is required to stand the work of our roads as they now exist.

Quite apart from the motor car question, it is a somewhat remarkable thing, particularly in a commercial

country such as our own, where facilities of transport are a prime consideration, that the economic importance of the question of the condition of the common roads is not more fully recognised. Probably it is the case that we have grown up accustomed to indifferent and hilly roads, and that the excessive cost of transport over them is not brought home to us because it does not directly affect the public at large. Any system of taxation for the improvement of the highways, on the other hand, would be felt directly, but there cannot be a doubt that money expended upon such improvement, whether under the supervision of a Government department or otherwise, would prove a most remunerative investment. Upon a level macadam road in a bad condition the pull required to haul a given load is about double that required upon a hard and smooth road. That is to say, that whereas a pull of 45 pounds suffices to haul a ton upon the good road, 90 pounds or more may be required on the bad. Upon asphalt the resistance is only about one half that upon good macadam, while upon gravel it may be three times as much. Again consider the loss due to gradients; with the moderate rise of one in twenty the pull required upon a good macadam road is increased to nearly four times; with a rise of one in ten it is increased to six times; if in addition to the gradient we have the surface in a bad condition, the pull required becomes twelve times that which is required upon a good level road. It is evident then that if we could reduce the gradients and maintain the surfaces of our roads in a uniformly good condition, that there would be a vast economy in horseflesh; fewer horses would be required to do the same work, or they would have a longer working life, and the saving to the commnnity direct and indirect would be very great.

Such an improvement would have a most important bearing upon the development of the motor car; it would enable the power and weight of the machine required to carry a given load, as well as the cost of maintenance, to

be considerably reduced, while the life of the machine would be prolonged. Again, it would render practicable the use of means of propulsion which so far have not met with great success on account of the weight to be carried.

The question of the roads has a most important bearing upon the historical aspect of the subject. Papin, the earliest steam carriage experimenter in Europe, after making a model in 1698, gave up the project because of the difficulties he foresaw in adapting the carriage for use upon ordinary roads. Symington, a century later, who also made a model, gave precisely the same reason for relinquishing further pursuit of the matter.

Vehicular traffic, properly so-called, is, after all, of comparatively modern growth. In early times each town and village was to a large extent an independent and self-sufficing community, and what little travelling or transport was required was effectively performed on horseback, so that the need for proper carriage roads did not exist.

In many quarters indeed there was a decided feeling that increased facilities for travelling were quite opposed to the welfare of the community. Soon after the introtroduction of stage coaches, about the middle of the seventeenth century, we find "A Lover of his Country" advocating their suppression as a national evil. They destroyed, said he, the breed of good horses, made men careless of horsemanship, so undermining their strength; deprived the watermen of work, and thus endangered one of the nursing-grounds of the Royal Navy, but more than all this: "Passage to London being so easy, Gentlemen came to London oftener than they need, and their Ladies either with them, or having the conveniences of these coaches, quickly follow them. And when they are there they must be in the Mode, have all the new Fashions, buy all their Cloathes there, and go to Plays, Balls and Treats, where they get such a habit of jollity, and a love of Gayety

and Pleasure, that nothing afterwards in the Country will serve them, if ever they should fix their minds to live there again."

Vehicular traffic, however, continued to grow, and in spite of the defective state of the roads. How bad they were a few examples will suffice to show.

As late as 1808 a leading stage coach proprietor, in his evidence before a Parliamentary Committee, stated that he had frequently known the road across Hounslow Heath to be two feet deep in mud. Arthur Young, in 1770, speaking of the road from Wigan to Preston, mentions ruts which he had found by measurement to be four feet deep, and floating with mud, and this after a wet summer only. He asks what the condition must be in winter-time. In 1791 the road from Grantham to Stamford was so cut up by ruts that a saddle horse could scarcely set down a foot with safety. All these were main roads. Turning to by-roads, we get a good illustration of their condition at the beginning of the eighteenth century in a letter from one servant of the Duke of Somerset at his house in London to another at his place at Petworth, Sussex. The writer states that the Duke intends to set out for Petworth on a certain day, and directs that the keepers and persons who knew the holes and the sloughs must come to meet his Grace with lanterns and long poles to help him on his way. Arthur Young furnishes us with another example in the state of the lanes of Essex in 1767. These he found so narrow that not a mouse could pass a carriage, and ruts of an incredible depth; waggons stuck fast until a line of them were in the same predicament and required twenty or thirty horses to be lashed together to each to draw them out, one by one. He had sometimes to alight from his chaise and get the rustics to assist him to lift it over a hedge before he could proceed.

Under these conditions travelling was anything but a pleasure, and no one but a crank or an enthusiast dreamed of travelling for the mere pleasure of seeing the

country. The tourist is the creation of quite modern times.

The defective condition of the roads naturally caused the transport of commodities thereupon to be both tedious and expensive, so that manufacturers strove as far as possible to avail themselves of water carriage, even at the expense of a greatly lengthened journey. Thus, we find Henri de Portal, at the middle of the eighteenth century, sending up the paper for the Bank of England notes from his mill at Laverstoke, in the north of Hampshire, mainly by water; the paper was taken by road to Newbury, Berkshire, there loaded upon a barge and brought down the river Kennet to Reading, and on by the Thames to London. In view of the great economy of water carriage, it is not surprising that the development of our industrial system was accompanied by the formation of canals and the general extension of internal water communication. To reduce still further the cost of transport and of the use of the common roads, tramways were laid down as feeders for the waterways, to connect the mine, forge or factory with a canal, a navigable river, or a port. The tramways acquired a system of mechanical propulsion in the form of the locomotive and developed into railways adapted for the conveyance of passengers as well as goods.

By the year 1824 a substantial improvement had been effected in the condition of the main roads; the good citizens of Canterbury were then able to congratulate themselves on being able to travel to London and back in a day. The run from London to Brighton was effected in five hours, and there were quite a number of coaches on the road. The Edinburgh mail ran through from London in forty hours with great punctuality. These were, indeed, the palmy days of the mail coach, and it was in competition with the mail coach that the steam carriage projectors of that remarkable period, 1820-1840, entered the field. The main thought with nearly all of

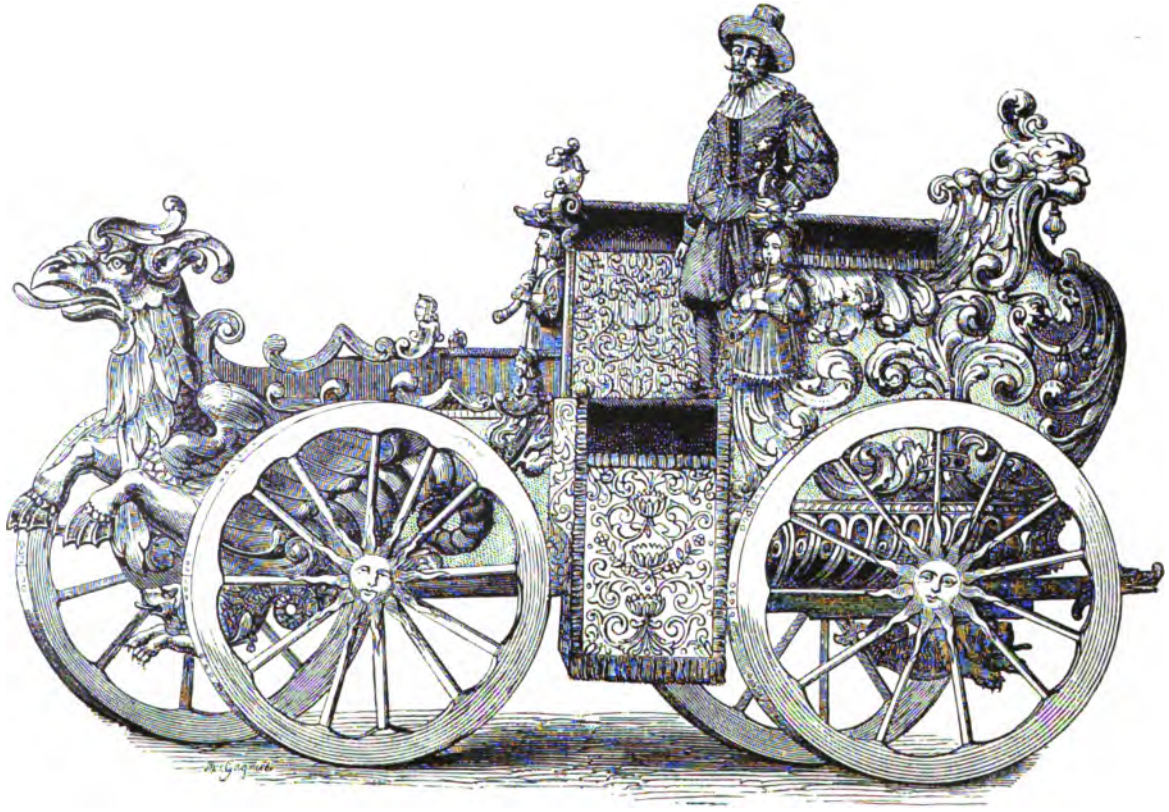
them was a steam coach—some of them indeed contemplated steam carriages for private use—but the great field was held to be in competition with the coach, and there was a consensus of opinion that heavy traction at low speeds was altogether out of the question. To comprehend the causes of the sudden outburst of energy at this period we must look to the steam engine. The spread of this motor in connection with mining and manufacturing industry had led to an extended knowledge of its capabilities, and to an immense development of the industrial activity of the country, thus acting, in the first instance, directly, by leading inventors to think out further applications and developments, and in the second, indirectly, by accentuating the need of improved means of internal communication. The first result of this was the improvement in the condition of the main roads, effected by Macadam, Telford and M'Neil, thus, for the first time, rendering possible, with any likelihood of success, the use of mechanical power thereon. The railways were, however, steadily developing, and wherever they appeared they soon monopolised the conveyance of passengers travelling over any considerable distance; from this and other causes, which will be discussed later on, the steam-carriage boom of 1820-1840 came to an abrupt termination.

The legislative enactments which followed some twenty years later effectually served to divert all future progress in self-propelled traffic in the direction of the traction engine and heavy slow-moving loads, and prevented the development in this country of any lighter and more rapidly moving types of vehicle, so that from 1840 to 1896, when the law was amended, it cannot be said that the motor car was a subject of much, if any, public interest in England.

The field of development during this period may be said to have been transferred to France, and it is to the French engineers that the credit must be accorded of having seen the special adaptability of the petrol motor for the

purpose of propelling light vehicles, and of carrying out the application in practice.

It was not until 1896 that the motor car in this country ceased to be in the eye of the law upon the same footing as the traction engine.



THE NUREMBERG MECHANICAL CARRIAGE, 1649.

CHAPTER II

ANIMAL POWER CARRIAGES

SOME form of self-moving apparatus is described before the Christian era as in use in the service of the temples, and Heliodorus in *The Ethiopics* mentions a triumphal waggon at Athens which was moved along by men carried therein; other authors also refer to such cars. An English writer mentions a similar contrivance used in Turkey in 1585: "Whilst I was remaining prisoner in Turkey . . I myselfe was there constrained to make a cunning peece of fire work framed in form like to ye Arke of Noy, being 24 yardes high, and eight yardes broad, wherein was placed 40 men, drawen on 6 wheeles, yet no man seene, but seemed to goe alone, as though it were onely drawen by two Fiery Dragons, in which shew or Arke there were thirteene thousand severall peeces of fire worke."[1]

There were also the moving forts and shields employed in besieging towns in the Middle Ages; but, although Friar Bacon had in the thirteenth century declared the possibility of making carriages go without animals, and Leonardo da Vinci (1452-1519) had sketched a form of self-moving car, no attempt appears to have been made in Europe before the beginning of the seventeenth century to apply any of these ideas to vehicles for travelling. In China carriages propelled by a rowing action and others fitted with sails

[1] *Edward Webbe, Chief Master Gunner, His Travailes*, 1590, Ed. Arber, p. 29.

were seen by European travellers in the fifteenth and sixteenth centuries, and had probably been in use in exactly the same forms for hundreds of years before.

Setting aside the attempt by the "ingenious fellow in Barkeshire," which is referred to in the chapter on "Carriages Propelled by the Wind," the first suggestion of the construction of a "carriage to go without horses" in this country is afforded by the petition of one John Marshall in 1625 for a patent for "a new invention of a cart of 15 c. weight to carry a great burden without help of horses and guided but by himself." The specific mention of the weight appears to indicate that the inventor had actually made a car. It is interesting to note here that the inventor presented his petition personally to the King at an audience in Whitehall.

Some years before this, in 1618, David Ramsey, a Page of the Bed-chamber to James I., and Thomas Wildgosse, gentleman, had obtained a patent for, among other things, ploughing without horses or oxen, and boats to go without sails. In 1634 the same Ramsey, then one of the Grooms of the Privy Chamber, was one of the partners in the grant of a patent for an invention which included "coaches, carts, drayes and other things goeing on wheeles."

No description of these inventions is known to be in existence, but it has been suggested that steam was the agent employed. There is really no ground for such a suggestion, and it seems far more likely that some form of manual power engine was in view in each case. A contemporary writer refers to ploughs worked by such means as having been made by H. Quarciotti, of Sienna.[1]

Sir Isaac Newton is credited with having made a manumotive carriage while at school in Grantham. This would be about the year 1655. Sir David Brewster says in reference to it:—

"The mechanical carriage which Sir Isaac is said to

[1] Harsdorffer, *Mathematischen und Philosophischen Erquickstunden*, 1651.

have invented was a four-wheeled vehicle, and was moved with a handle or winch wrought by the person who sat in it. We can find no distinct information respecting its construction or use, but it must have resembled a Merlin's chair, which is fitted only to move on the smooth surface of a floor, and not to overcome the inequalities of a common road."[1] Merlin's chairs, it should be explained, were wheeled chairs for invalids named after the maker, a French mathematical instrument maker who came to London in 1760.

Beyond this it does not appear that anything was actually done in this country during the seventeenth century in the direction of self-propelled vehicles, and in view of the backward state of the mechanical arts this is not very surprising. A number of attempts were however made to improve road vehicles. Thus in Birch's *History of the Royal Society* we read in 1663 of Mr Potter's cart with legs instead of wheels, and in the discussion upon the construction of a new carriage, the invention of the Duc de Roanez, the celebrated Hooke presented the Society with the "Scheme of an instrument to walk in upon the land or water with swiftness after the manner of the wheel of a crane." This description does not enable one to form an idea of the nature of the invention, which was probably the same as that for which Hooke obtained a patent in 1664. The inventor seems to have taken steps to carry the invention into practice, judging by an entry in Evelyn's *Diary* under date 4th August 1665: "On my return I called at Durdans, where I found Dr Wilkins, Sir William Petty and Mr Hooke contriving chariots, new rigging for ships, *a wheele for one to run races in*, and other mechanical inventions." This description seems to suggest something in the nature of a velocipede, but nothing further is known of the invention.

Numerous attempts were in fact made to improve

[1] D. Brewster, *Memoirs of the Life, Writings and Discoveries of Sir Isaac Newton*, 1855. Vol. i., p. 10.

road carriages at this time, and about 1665 Dr Peter Chamberlain sought for a patent for "the sole making of coaches, waggons, carts, ploughs, to go without horses, such as he saw at Augsburg 50 years past," but nothing seems to have come of his application.

In 1667 a patent was granted to Sir Ellis Leighton for "A c'teine Engine w^{ch} Wrought and Disposed into the Bodyes and Carryages of Waggons, Chariotts, Coaches, and all Sorts of Things w^{ch} are used for Carrying of persons and Burthens from One Place to Another by Land, will Facilitate to the Mōcon of all these Things, that it will extreamly save the Toyle and Labour both of Men and Horses, and Soe consequently performe their severall uses with lesse Expense."

This invention is alluded to in a letter dated 1688, from Oldenburg, the Secretary of the Royal Society, to Lord Brereton, from which it is clear that the invention consisted of some means for reducing the resistances to traction, and that horses were not dispensed with entirely.[1] From the entry in Evelyn's *Diary*, September 29, 1668, "I went to see Sir Elias Leighton's project of a cart with iron axletrees," it would seem that the invention was a very simple one. But it is difficult to avoid thinking that there must have been something more than the mere use of iron for axletrees, which had already been patented, to justify the terms used by Oldenburg, to say nothing of the title of the invention in the patent.

For the earliest record of a successfully constructed mechanical carriage for travelling on ordinary roads we

[1] "I saw yesternight a cart leaden with at least 600 bricks, whereof each by weight weighed about four pounds, drawn by one horse in an uneven and ascending way, by a new contrivance, which avoydeth rubbing much more than ordinary carts. It has been devised as I mentioned formerly, by the concurrence of persons of several nations; and the patent of them is given in divers contry's; here to the Duke of Monmouth, and to Sir Ellis Leyton (as himself told me), and at Paris to some great persons; as also in Flanders. In the meantime, our mathematicall mechanicians doe not want exceptions against the extraordinariness of the contrivance."—Halliwell, *Letters on Scientific Subjects.*

must turn to Germany and to the town of Nuremberg, then the Birmingham of Europe, where in 1649 the performances of a road vehicle propelled without the aid of horses was causing a considerable sensation. This carriage was the work of the celebrated mechanician, Johann Hautsch, and, as shown in the illustration, p. 12, was of a highly ornate design. The drawing affords no clue to the nature of the driving mechanism employed, but from the accounts of contemporary writers[1] there appears to be no doubt that the carriage was worked by two men concealed in the interior, who turned the rear axle by means of winch handles and a train of gearing. This carriage was a complete success, at anyrate upon the streets of the town. It went up and down hills, was steered around corners, and stopped and started as desired, and attained a speed of 2000 paces an hour. It was adapted for carrying several passengers, and the dragon in front was contrived to spout out a stream of water for the purpose of clearing the way in a crowd. This is a very fine idea, but perhaps was intended to be used only as a last resource, for the dragon could turn its eyes to and fro with great rapidity. And if this did not frighten people out of the way, the angels, mounted one on each side of the carriage, were caused to sound their trumpets.

Hautsch's first carriage was sold to the Crown Prince of Sweden, and another of the same construction was afterwards made for the King of Denmark.

Another and contemporary Nuremberg mechanician, Stephan Farfler, also constructed manumotive carriages, but on a smaller scale than those of Hautsch. They were, in fact, built to carry one person only, who propelled himself by means of a pair of winch handles, on the spindle

[1] Harsdorffer, G. P., *Mathematischen und Philosophischen Erquickstunden*, 1651. *Journal des Voyages de Monsieur de Monconys*, 1666. Doppelmayr, *Historische Nachricht von den Nürnbergischen Mathematicis und Künstlern*, 1730.

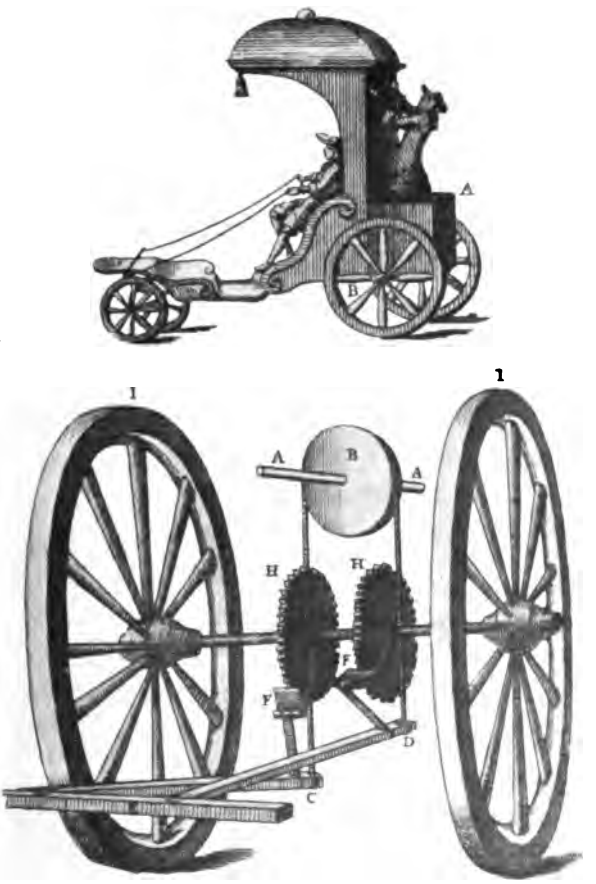
of which was a pinion in gear with the toothed periphery of the front wheel of the carriage, and must be regarded as the forerunners of the modern tricycle. By the aid of one of these carriages, Farfler, who was lame, was able to make his way about the town without assistance.

About the same period another mechanical carriage is stated to have been made at Bingen.

Hautsch, before building his carriage, had tried his skill upon a wheeled chair, which was contrived to be moved about a room by mechanism worked by the occupant. Such a chair had, however, been described before this by a French writer, Mathurin Jousse, in his *La Fidelle Ouverture de l'Art de Serrurie*, 1627, in which are drawings of two chairs. The one chair is fitted with roller castors, and the other with castors under the front legs and wheels under the hind legs, which wheels are geared to a spindle provided with winch handles adapted to be turned by the person seated in the chair.

Towards the end of the seventeenth century a very successful pedomotive carriage made its appearance in Paris. It was the invention of Elie Richard, a physician of La Rochelle and a man of science of some note. As will be seen by the drawing, it was propelled by a servant, in the box behind, who rotated the hind wheels I by means of treadles C, D acting through pawls F and ratchet wheels H; the treadles were coupled by a cord passing over a pulley B, so that the descent of one caused the ascent of the other ready for the next downstroke. The passenger steered the vehicle by means of cords connected to a crossbar fixed to the axle of the front wheels. Ozanam (*Recreations Mathematiques et Physiques*, 1694), in describing this vehicle, speaks of it as "un carosse, dans lequel on se puisse conduire soy-même là où l'on voudra, sans aucuns Chevaux." It is clear that this is not quite correct, as a servant is required to work the machine. Hooper, however (*Rational Recreations*, 1774), points out that by bringing the treadles to the front, the carriage

may be propelled by the passenger himself, and he remarks that "a machine of this kind will afford a salutary recreation in a garden, or park, or on any plain ground,



RICHARD'S MECHANICAL CARRIAGE, *CIRCA* 1690.

but on a rough or deep road must be attended with more pain than pleasure."

During the eighteenth century a good deal of attention was devoted to the problem of providing carriages with

self-contained means for propulsion, but although many schemes were broached, the number actually carried into effect appears to have been comparatively small.

In the London newspapers of 1711 will be found the advertisement of a man who proposed to supply carriages to go without horses.

"An invention of a wonderful chariot in which Persons may travel several miles an Hour, without the assistance of Horses, and measure the Miles as they go; it turns or goes back; having the Praise of all Persons of Quality, and ingenious Men that have seen it. Note that it is convenient for any Gentleman that is incapable of walking thro' lameness, to ride about his Park or Garden, without damaging his Tarris-walks or Grass-plats. The invention is so highly approved that there is one already bespoke by a Person of Quality, which is to go on four Wheels, and swing in the nature of a large Coach, which according to a modest Computation will travel at the rate of 7 or 8 miles an Hour. If any Person of Quality is desirous to use them with Horses, they may either travel as far again in a Day as they can with another Coach, or run as far with a pair of Horses, as the Coaches hitherto in use can with 6. Note that such as are bespoke for Parks or Gardens only, will come very reasonable, others at proportionable Prices."

It would appear that a carriage or carriages had been actually constructed, but the scheme did not take, for nothing further is heard of it.

The broad idea that a carriage could be propelled by a man turning a winch must have been tolerably familiar in this country by the middle of the century. Emerson's *Mechanics*, 1758, has a drawing of such a vehicle, and the magazines of 1769 published drawings of carriages like that of Richard. The matter had at this latter date been brought into some prominence in consequence of the discussions on Moore's carriages for travelling without horses, which were then receiving much attention. Since

the consideration of Moore's project is to some extent bound up with that of steam carriages it will be deferred.

A "machine cart . . . in its full magnitude" was, in 1768, presented to the Society of Arts by a Mr George Black of Berwick-upon-Tweed. It could be propelled, when loaded, by one man, but the main object of the inventor was to provide means for assisting a horse over a difficult bit of road.

The German mechanical carriages of this period do not call for particular consideration here. A number of them will be found mentioned in Busch's *Handbuch der Erfindungen.*

Of the French carriages, that of Beza (1710), intended for the use of invalids, consisted of a chair secured to a platform on wheels, and the axle of the rear wheels was driven from a winch by means of a positive driving band which had a row of holes to work over pins projecting from the pulleys. Maillard's vehicle, intended for general use on the road, was worked by a servant, seated behind the passenger, by means of a winch and cogwheels; a fly wheel is a noticeable feature in this machine. Maillard also devised a machine for a single rider.[1] Brodier's machine, 1763, was really a tricycle which the rider worked by means of crank handles, on the spindles of which were toothed or cam discs to engage with and drive small discs fixed on the spokes of the two large wheels; the small rear wheel was carried in a fork fitted to swivel in a vertical socket for steering.[2]

A carriage very similar to that of Elie Richard was brought out in Paris in 1779 by Blanchard and Masurier; it attracted considerable attention and worked very well.

In the present century, just before the days of railways,

[1] These machines are described and illustrated in *Machines et Inventions approuvées par l'Académie Royale des Sciences.*

[2] Described with full particulars as to weight and performance in the *Mémoires* of the French Academy for 1763.

we read of a number of manumotive and pedomotive carriages.

Cartwright, the inventor of the power loom, turned his attention to the subject. He had discovered what he considered to be a new way of employing human power—*i.e.*, by the combination of weight and muscular action, which he applied in a carriage. In a paper in the *Philosophical Magazine* for 1819, entitled "On a New Method of applying the Power of Man to the moving of Machinery, with at least Six Times the Effect that can be produced by mere Muscular Exertion," he says: "As there is not a shadow of a doubt but that an able-bodied man can, in this way, exert the power of a horse, I should not despair of seeing, were I to live but a few years longer, carriages of every description travelling the public road without the aid of horses."

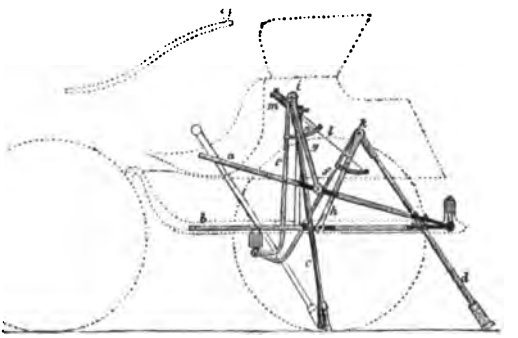
A few years later, in a letter dated 1822, he writes: "I have completed my invention of a carriage to go without horses, which I call a centaur carriage. Two men, took a cart from my house (the cart and its load weighing sixteen cwt.) a distance of twenty-seven miles in a day, and up two very long and steep hills. Since then I have greatly improved upon it. It is now so constructed that I can give it what speed I please."

The arrangement comprised a pair of treadles and cranks, worked alternately by the feet of the driver, and of shoulder-straps fixed to the carriage.

A Leeds cutler named John Baynes devised in 1819 an arrangement in which the carriage was propelled by legs or pushers worked by treadles. In the figure *c*, *d* are the legs jointed to arms *e*, *f*, and connected by links *g*, *h* to the treadles *a*, *b*. When the treadle *a* is depressed the end of the leg *c* is pressed against the ground, and by virtue of its connection, by means of the arm *e* and treadle *a*, with the carriage, pushes the latter along. The treadle *a* in its downward motion, by means of a cord *l* passing over a pulley, pulls up the treadle *b*, thereby shifting

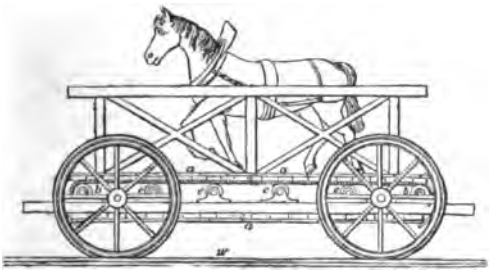
the leg *d* into the position in which the leg *c* is shown.

A carriage propelled by treadles was made in 1827 at Sunderland; it is said to have carried seven persons; and three years later Isaac Brown of Bingley, Yorkshire, made a wonderful wooden horse which drew a gig over a mile in six minutes. About 1833, just about the time of the great steam-carriage boom, a scheme was put forward for establishing a system of public conveyances in London to be worked by manumotive engines.



BAYNES' CARRIAGE, WITH LEGS, 1819.

The animal power carriages so far described were all intended to be worked by men. It remained for the ingenious inventor to arrive to take the horse from the shafts and place him on board the vehicle, and it is somewhat singular to relate that George Stephenson, who has been called "the father of the locomotive," was himself the father of one of these schemes, but there is a letter by him at the South Kensington Museum, addressed to Timothy Hackworth, in which he claims the invention of Brandreth's



BRANDRETH'S CYCLOPEDE, 1829.

"Cyclopede," and states that he had contemplated using it on the Canterbury and Whitstable Railway.

Brandreth's Cyclopede, the construction of which is clearly shown in the illustration, consisted of a carriage having for its bottom an endless platform *a* supported on rollers *b*, *e*; the axle of one of the rollers *b* is geared to one of the axles of the vehicle and the horse is tethered in the carriage with his feet on the platform, so that in endeavouring to move forward his feet constantly press the platform backwards, and thus impart motion to the wheels. This machine was tried with the "Rocket" and other locomotives at the Rainhill competition on the Liverpool and Manchester Railway in 1829. It was found impossible to attain speeds higher than five or six miles an hour.

The idea of mounting the horse on the carriage is much older than this; for instance, in 1824, we have the curious contrivance shown which was the invention of W. F. Snowden, "Mechanist," of Oxford Street, London.

This carriage has an upper storey for the passengers, and a lower storey for goods and for the horses, which walk around on a circular track, and by means of yokes and radial arms rotate a central vertical shaft to which the axles of the road-wheels are connected by toothed gearing. This project, as a whole, is perhaps more curious than valuable.

Snowden's invention comprised also a railway with an underground continuous rack. The carriage, when used for this purpose, had the central vertical shaft prolonged to pass through a longitudinal slot in the roadbed, such as we now see on cable railways, and carried a cogwheel engaging with the rack. The figure, in fact, represents this application of the carriage, and clearly shows the slot. For use on ordinary roads, the spindle *s* was fitted at its lower end with a pinion working into a toothed segment fixed to, and projecting from, the front axle, so that this might be turned one way or the other for steering purposes.

In Curtis's "Animal Locomotive or Machine for multiplying the Velocity of Beasts of Burden," 1835, the horse is employed to work treadles connected to cranks. This and other projects of the same inventor are described in his *Inventions for Railways*, 1840.

As recently as 1850 a machine of this description, the in-

SNOWDEN'S CARRIAGE, 1824.

vention of an Italian, Signor Clemente Masserano, was tried at the Nine Elms terminus of the South-Western Railway. In this case two horses were tethered in a car and worked a rotating platform, the motion of which was transmitted to one of the axles by means of a band and pulleys. The inventor talked of speeds up to sixty miles an hour, on a railway, but the speed actually attained about the station was seven miles an hour.

These schemes look rather absurd, but the idea upon which they are based, the attainment of high speeds without the necessity of causing the animals to travel faster than the speed at which they do the maximum amount of work, is quite sound.

CHAPTER III

SPRING-MOTOR CARRIAGES

THE first attempt to propel vehicles by means of power stored in springs, of which any account is extant, is that made in Paris in 1644 by an Englishman. Neither the name of the man nor the construction he adopted are recorded, but according to Guy Patin the carriage was intended to perform the journey from Paris to Fontainebleau and back in one day "sans chevaux par des ressorts admirables," and it was considered that if the scheme succeeded there would be a great economy as hay and oats were then very dear. It appears that the carriage worked very well in a room, but the labour of winding up the springs, which was performed by men, was so great that there was no economy as compared with horse traction, and the project was consequently abandoned.

La Veuve Montarbault, a well-known French adventuress, was associated with the Englishman in the project.[1]

The next attempt with a spring motor was that of Vegelius, a professor at Jena, who in 1679 made himself a mechanical horse in which the motive power was stored

[1] "Sa beauté commencant à diminuer, elle se mit a souffler (to practise alchemy); elle avoit un million de secrets, et voyant qu'elle se descrioit à Paris, elle alloit faire de petits voyages dans les provinces. . . . Après plusieurs promenades, elle rencontra un Anglois qui se vantoit d'avoir trouvé l'invention de faire des carrosses qui *iroient* par ressort; elle s'associe avec cet homme, et dans le Temple ils commencerent à travailler à ces machines. On en fût un pour essayer, qui veritablement alloit fort bien dans une salle, mais n'eust pu aller ailleurs, et il falloit deux hommes qui incessamment remuoient deux especes de manivelles, ce qu'ils n'eussent pu faire tout un jour sans se relayer; ainsy cela eust plus cousté que des chevaux."—*Les Historiettes de Tallemant des Reaux*. Paris, 1862. 3rd edition. P. 340, tome iii.

in springs. This machine was clothed with the skin of a real horse, and, on level ground, was able to cover four German miles in a day;[1] but it is not stated how frequently the professor had to dismount to wind up the springs.

About the middle of the next century there is an account of another Englishman endeavouring to get a spring-motor carriage taken up on the Continent, this time in Holland, and apparently without success.[2]

The project of Genevois (1760) will be mentioned in connection with sailing carriages. His "great principle" was to store power, by whatever means produced, in a series of springs, and then to apply it as and when required. In connection with sailing road vehicles the springs were to serve as auxiliary means of propulsion, to be employed when the wind failed or its direction did not serve. Mainly his thoughts turned to marine pro-

[1] "Le sieur Vegelius, Professeur de Mathematiques à Jenne en Saxe tres habile en mecanique a fait un Cheval d'Airain, dans laquel il a mis un ressort si admirable qu'il donne à ce cheval qu'il revest d'une peau de veritable Cheval, un mouvement assez fort et assez continuel pour lui faire dans un jour d'automne quatre mille d'Allemagne, c'est-a-dire 8 lieuës de France, pourveu que ce soit en platte Campagne."—*Le Journal des Scavans*, 1680.

[2] "Some years ago an English gentleman came to the Hague, and lodged in the same house with me. He told me that he had offered his services to several of the nobility and others in England, in order to make them coaches and chariots of a new invention, which were to go by springs without horses; and that he had met with no encouragement; that, as Holland was a perfect plain, and the road as smooth as a floor, they had advised him to try the Hague. He seemed to be a great mathematician, and discoursed so profoundly on the laws of motion, and everything that related to mechanical learning, that, having at that time just begun the study of philosophy, I did not sufficiently understand him; but those who did thought him a prodigy in that science. I have since reflected that if this ingenious gentleman had made a small chariot, or other machine, by way of model, and set it in motion in a large room, or on a garden walk, such a demonstration would have given more satisfaction than all his profound reasonings, and the draughts which he had made upon paper. I found he had not seen the Elector of Saxony's cabinet of varieties at Dresden, nor those at Augsburg and Nuremberg, which was a pity, as they contain the noblest collection of such curiosities in the world.

"The gentleman changed his quarters, so that what success he met with at the Hague I know not; but I believe with none, for there is nothing of that kind either there or in any other part of Holland.—*The Present State of Holland*, 1765.

pulsion, and there he proposed to use the steam engine or a gunpowder engine to compress the springs.

Since then a large number of projects have been put forward for working carriages by means of springs, and in 1870 a clockwork omnibus was actually being tried on the streets of New Orleans. In the same year a French inventor gave out that his four-wheeled carriage with three passengers on board could travel at the rate of nine or ten miles an hour, and that his springs required winding only once an hour, which could be done while the carriage was in motion.

The most completely worked out scheme, however, is that of E. H. Leveaux, of Brook Green, who proposed, in 1873, to use a series of springs under the floor of the car, which were to be wound up by stationary steam engines placed at suitable intervals along the road. A company or syndicate was formed to work the system, and they constructed a number of the motors of two-horse power and under.

The relatively enormous weight of metal to be carried in order to store a given amount of energy is so great that no success can be expected with spring motors, and this is now generally understood; still, in 1895 and 1896, when the motor-car movement began to make headway, a number of inventors experimented with spring-motor carriages.

CHAPTER IV

CARRIAGES PROPELLED BY THE WIND

THE idea of utilising the power of the wind for the propulsion of land vehicles is one that must have presented itself to thoughtful minds from a very early period. The advantages of making use of a source of energy, external to the vehicle, and free to all, are manifest, but the disadvantages of the wind, its unreliableness, its variability in force and direction are also fairly obvious, so it is not surprising that the many schemes which have been from time to time put forward for this purpose have come to nought. These schemes are indeed interesting, but of no practical importance nowadays.

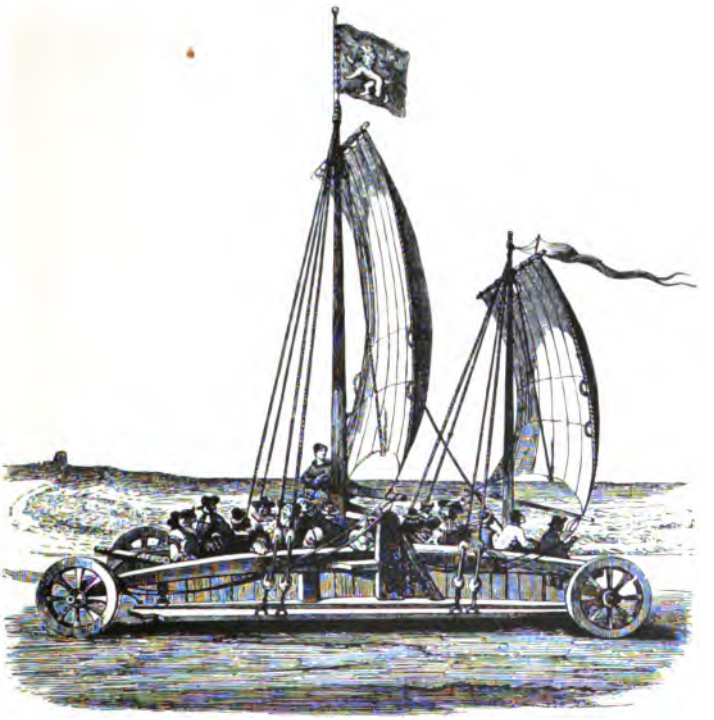
From very remote times sailing carriages have been used in China. One of the earliest collections of travels in the English language, that of Purchas, refers to them:—

"Of Corea he (Capt. Saris) was also told, that there are many bogs, for which cause they have waggons with broad wheeles, to keep them frõ sinking, and observing the Monson or Season of the wind (of which you have heard how certain it comes yerely in all the East) they have sails fitted to those waggons, and so make their voyages on the land. With such waggons full of soldiers *Taicosama* (as he was told) had intended to assaile China, but was prevented by One, which to poison him, poisoned himselfe."[1]

The first sailing carriages seen in Europe were made in Holland about the year 1600 by the celebrated mathematician Simon Stevin (born at Bruges 1548, died 1620).

[1] *Purchas his Pilgrimage.* 3rd edition, 1617, p. 684.

Stevin built two carriages, one of large size capable of carrying twenty-eight passengers, the other of smaller size adapted for five passengers. Both appear to have run very successfully when the wind served. Our illustration depicts the larger carriage, which, it will be seen, consisted



STEVIN'S SAILING CHARIOT, *CIRCA* 1600.

of a rectangular open-topped box provided with two sails and mounted on two pairs of wheels; the axle of the hind wheels was pivoted to the box and fitted with a steering handle.

An account of a journey made in this carriage, apparently in the year 1600, is given in a pamphlet bearing the title, *Windt-Wagens, des Artificiels Chariots à Voiles*

du Compte Maurice, which may possibly have been issued with the original engraving. It is accompanied by a diagram of the steering apparatus, and is printed in French, Dutch and Latin. According to this account a run of forty-two miles along the Dutch coast from Scheveningen to Petten was performed in two hours, or at the rate of twenty-one miles an hour, a speed which would seem almost incredible but that we know that even higher speeds have been attained with similar vehicles. There were twenty-eight persons on board, including Prince Maurice himself, who steered; Grotius, then a lad of fifteen; and the Spanish Admiral, Francis Mendoza, who was at the time a prisoner in the hands of Prince Maurice. The trial trip appears to have been a great success, but in spite of this there is no record of its having been used on any subsequent occasion, and, stranger still, it is not known what became of the carriage in the end.

Howell in his *Letters* (1650) refers to it as one of two wonderful things to be seen near the Hague:—

"A waggon, or ship, or a monster mixed of both, like the Hippocentaur, who was half man and half horse; this engine that hath wheels and sails, will hold above twenty people, and goes with the wind, being drawn or mov'd by nothing else, and will run, the wind being good, and the sails hois'd up, above fifteen miles an hour upon the even hard sands: they say this invention was found out to entertain Spinola when he came hither to treat of the last truce."

Another writer,[1] in 1765, remarks that Scheveningen is famous for the sailing chariot kept there, which according to his account had not been used since about 1748. This was probably the smaller carriage mentioned above; it was to be seen at Scheveningen as lately as 1802, but its fate since that date is not known. The contemplation of Stevin's contrivances appears to have led this writer to a

[1] *The Present State of Holland*, 1765.

little experiment on his own account, as to which he somewhat quaintly says:—

"I once made an experiment of this kind on a child's chair, by doing some things to it, and adding a sail, which succeeded beyond expectation, but with an unforeseen circumstance, that was very near giving me great cause to regret my mechanism. For the wind being brisk, carried away the little machine and passengers in it with such rapidity, that myself, as well as the nurse, who almost swooned away, was in no small terror. There was indeed a precipice before it which I thought at too great a distance for any danger. The sailing chair had almost reached the brink of it, before I could overtake to stop it; and my being able to do so was more owing to some large pebbles that retarded the motion than my own speed, though I ran as fast as I could."

WILKINS' WINDMILL CARRIAGE, 1648.

Readers of *Tristram Shandy* will recollect that Dr Slop walked from the Hague to Scheveningen with the object of inspecting one of Stevin's carriages. His remarks thereon are, however, taken almost bodily, with the exception of a little addition in the manner of Sterne, from a work by Bishop Wilkins printed over a hundred years before.[1] The Bishop, in treating "Of a sailing chariot, that

[1] *Mathematicall Magick* by J. W., M.A., London, 1648.

may without horses be driven on the land by the wind as ships are on sea," remarks that: "I have often wondered why none of our gentry who live near great plains, and smooth champions, have attempted anything to this purpose. The experiments of this kind being very pleasant, and not costly, what could be more delightful or better husbandry than to make use of the *wind* (which costs nothing, and eats nothing) instead of *horses*? This being very easy to be effected by those the convenience of whose habitations doth accommodate them for such experiments."

He gives us a drawing purpo ting to represent Stevin's carriage, which has been reproduced frequently by other writers. This drawing was, however, prepared from descriptions by persons who had seen the carriage, so that although it indicates the essential features, it does not bring out the actual construction. The substitution of windmills for sails is suggested in this work, and in Emerson's *Mechanics*, 1758, a modified plan is indicated. In 1784 a Mr Dornforth presented the Society of Arts with a model of such a carriage, but it is not known whether a full-size carriage so propelled was ever constructed in this country.

Two plans for propelling waggons by windmills were proposed in France by M. Du Quet in 1714. In the first of these the power of the mill is transmitted to two pairs of inclined pivoted legs, one pair on each side of the waggon; the legs of each pair are alternately thrust backward and retracted, thereby pushing forward the machine. The steering gear possesses points of interest, comprising as it does separately pivoted axles for each of the front wheels, a feature to be met with in the motor carriages of the present day. In the second waggon the power of the windmill is used to impart motion to the wheels by means of ratchet bars and pinions. A boat propelled in the same manner was tried at Le Havre, and it is said with success.[1]

[1] *Recueil des Machines approuvées par l'Académie des Sciences.* Tome iii., 1714.

To go back to the sailing vehicle, very soon after the construction of Stevin's vehicle we read[1] of "an ingenious fellow in Barkeshire," who in 1607 "sailed or went over a high steeple in a boat, all of his own making; and without other help than himself in her, conveyed her about 20 miles by land, over hills and dales, to the river and so down to London." This puts Stevin completely in the shade, but the story is too good to be true. One would like, for instance, to learn something more of that voyage over the steeple.

A winged cart which could move against the wind, or even when the wind failed altogether, a result which was to be attained by the storage of energy in springs, is described by J. H. Genevois, a minister in the Canton of Berne, Switzerland, in a little book which bears the title. *Some New Inquiries tending to the Improvement of Navigation*, London, 1760, which purports to be an abridgment, prepared at the request of the Lords of the Admiralty, of a larger work by the same author.

A project for storing the power of the wind for the purpose of effecting the propulsion of road vehicles was put forward in the year 1800 by George Medhurst. He proposed to employ stationary windmills to work pumps by which air was to be compressed into reservoirs in the cars, and the cars were to be operated by compressed-air engines. This scheme will be found discussed in the chapter on "Compressed-air carriages."

In 1776 there is an account of a French carriage in which a sail was used as an auxiliary. Unfortunately the account is very imperfect, but it states that the carriage went without the aid of an animal, was simple and light, and had no weights, springs or balances in its mechanism, and that it could be set in operation by a child. The inventor was Phillipe-Alexis Stemon, a carver and joiner of Avallon in Burgundy.

Towards the end of the eighteenth century an English-

[1] Letter reproduced in *Notes and Queries*, 3rd series, vol. iv., p. 194.

man, Slater, made a journey in a sailing waggon from Alexandria to Bassora, and in 1786 trial was made of another on Blackheath, at which Sir Joseph Banks and other members of the Royal Society were present. It appears that the machine went at a great speed until the mast broke.

In 1820 a sailing carriage was used near Newmarket, and, coming to more modern times, many will call to mind the "Flying Dutchmen," which were some years ago to be seen careering about the sands at Southport, and a recent issue of a popular magazine gave an account of a sailing carriage at present in use on the Mojave Desert in Southern California, with which speeds of fifty miles per hour are said to have been attained.[1]

The most successful attempts at the application of the power of the wind for the propulsion of vehicles on land have, however, been made in connection with railways. As far back as the end of the seventeenth century we find a most interesting experiment being made in connection with the propulsion of colliery waggons along a plate or tramway at Neath in South Wales. Sir Humphrey Mackworth, a well-known mining proprietor of those days, had become possessed of mining property in that locality about the year 1695, and being a man of considerable enterprise, sought among other things to increase his coal shipments, to which end he very soon introduced the system of waggon-ways from Newcastle and Shropshire, and upon the waggons he applied sails.

A contemporary writer[2] says of him that "his new Sailing-waggons for the Cheap Carriage of his Coal to the Water-side, whereby one Horse does the Work of ten at all times; but when any Wind is stirring (which is seldom wanting near the Sea) one Man and a small Sail does the Work of twenty (which are publick), do sufficiently

[1] *The Strand Magazine*, April 1902.

[2] *An Essay on the Value of the Mines, late of Sir Carberry Price*, by William Waller, gent., steward of the said mines. London, 1698.

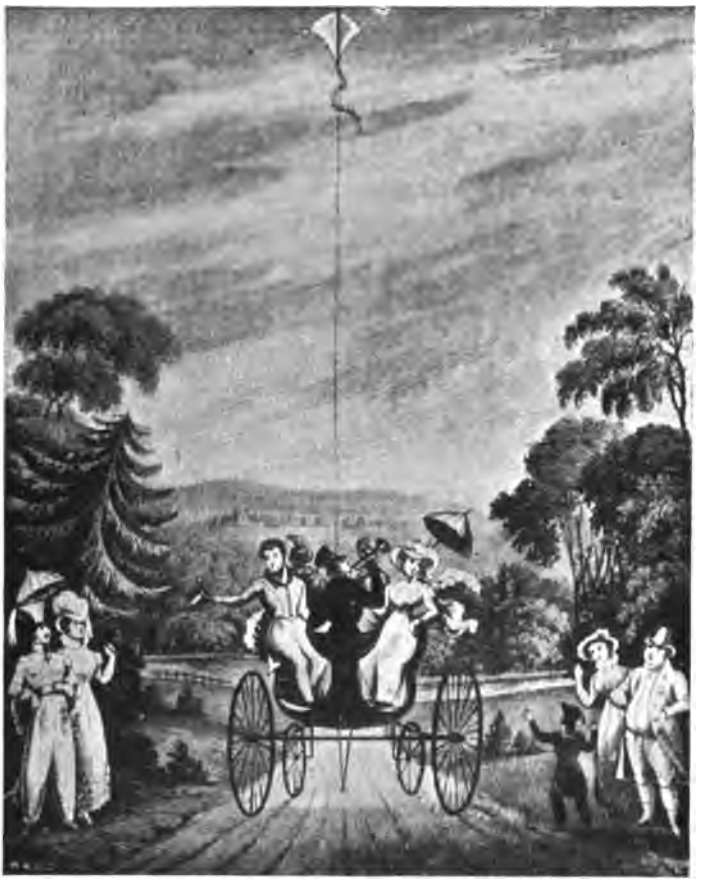
show what his Genius is capable of in matters of that nature.

"And, I believe, he is the first Gentleman, in this part of the World, that hath set up Sailing-engines on Land, driven by the Wind, not for any Curiosity, or vain Applause, but for real Profit, whereby he could not fail of Bishop Wilkins' Blessing on his Undertakings, in case he were in a capacity to bestow it."

But this application, in spite of its great utility, did not endure for more than a few years. Sir Humphrey became involved in difficulties of one kind and another, and the highway authorities objected to the tramway being carried across the highroad, and finally took it up at that point, thereby breaking the connection between the mines and the river. Portions of the foundations of this tramway are still to be seen, or were so until a few years ago.

After Sir Humphrey Mackworth's attempt, the project of propelling railway waggons by sails remained in abeyance until the beginning of the nineteenth century, from which period onwards quite a number of isolated attempts are recorded. The journals of the year 1834 mention an experiment made by a ship captain at Llanelly in South Wales, in which a distance of three miles, including a steep incline, was covered in 7½ minutes, and two years later we have a somewhat glowing account of the results of an experiment made on the Durham and Sunderland Railways. In America the plan has been tried from time to time since 1830; and so recently as 1878, the *Scientific American* gave an illustrated description of a sailing car devised by Mr C. J. Bascom of the Kansas Pacific Railroad which had been in use for the preceding three years for conveying repairing-parties to pumps, telegraph lines and the like along the line of railway. The average speed attained is stated to have been twenty miles per hour, but the drawing must have been made to show the effects of a strong breeze, as the occupants of the car appear to be exerting their full strength in holding on.

The "charvolant" or kite carriage of Viney & Pocock embodies a method of applying the power of the wind



VINEY AND POCOCK'S "CHARVOLANT" OR KITE CARRIAGE 1827.

which is quite distinct from any of those mentioned in the foregoing account. These inventors employed one or more kites arranged in tandem to pull a light carriage. The construction of the kites is thus described by Mr Pocock :—[1]

[1] *Navigation in the Air by the Use of Kites or Buoyant Sails*, 1827.

"The shape may vary, but for what is termed the Pilot, or uppermost Kite, the common circular-headed shape is certainly best. The first peculiarity of this invention is, that the kite is made to fold up, the standard of the kite is divided into two equal lengths, or in three if the kite is very large; the wings also have hinges or joints at the top of the kite; and if very large, each wing is divided into two parts.

"In the second part of the invention, two lines are used for what is termed the belly-band; the upper one stationary or fixed; the under one, termed the lower brace line, reeves through an eye in the upper line, at about the distance where the usual bow is tied in the belly-band of the common kite. Both these lines are continued down to the hand of the controller. By straining on the lower brace, the kite is brought up against the wind, into full action; by slackening the same, the kite is laid inactively upon the wind: thus its power is instantly increased or lessened while floating in the air. By these same means the kite is elevated or lowered at pleasure, soaring or sinking in proportion as the angle is formed on the kite's surface.

"Another branch of this system consists of the application of two side lines, one attached to the right-hand extremity of the kite, and the other to the left. These act upon the kite much the same as the reins do upon a gig-horse; by pulling the right-hand line, an obliquity is given to the kite's surface, on which obliquity the wind acting, the kite veers instantly to the right hand; straining on the left-hand brace, the action is directly *vice versâ*."

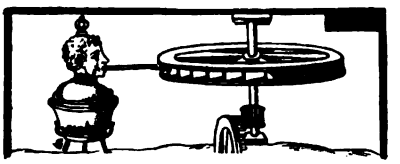
The carriage was fitted with a spring drag operated by a lever for the purpose of arresting or retarding its motion. It was steered by means of a vertical spindle, the lower end of which carried a pulley which was connected by a band to another pulley on a vertical pivot in the centre of the front axle. To make the carriage available when the wind did not serve, it was proposed

to secure a platform behind for the purpose of carrying a pony. A carriage constructed on this system in 1826 or 1827 performed the journey from Bristol to London, and was frequently to be seen in Hyde Park and in the northern suburbs of London. It is stated that a speed of a mile in three minutes was attained on several occasions, even upon heavy roads, and that upon one occasion the mile was covered in $2\frac{3}{4}$ minutes. In reference to the power of the kites, Mr Pocock states that a man of moderate strength could just hold a kite twelve feet high, having an area of forty-nine square feet against a wind blowing at the rate of twenty miles an hour, and that with a rather stronger wind the kite broke a string capable of sustaining a weight of 200 pounds.

CHAPTER V

THE EARLY ATTEMPTS TO APPLY STEAM POWER TO ROAD VEHICLES.

THE projects of David Ramsey and others, for ploughing without horses or oxen, for boats to go without sails, and for "coaches, carts, drayes and other things goeing on wheeles," have been alluded to in a preceding chapter (p. 6), when it was explained that the suggestion thrown out by some authorities to the effect that steam was the agent employed was quite without foundation, and so far as is known the earliest application of the power of steam to the propulsion of vehicles was made by Father Verbiest, a Jesuit missionary (born near Courtrai, 1623; died in China, 1688). Verbiest appears to have spent a considerable part of his life in China; he acquired a mastery of the language, and under a Chinese name wrote quite a number of scientific and theological works therein.[1] He appears to have been a man of remarkable ability, and in spite of a strong native opposition was high in favour with the Emperor. He was appointed Astronomer Royal at Pekin, undertook the reformation of the Chinese calendar, and superintended cannon foundries.



THE EOLIPILE.

[1] The best account of Verbiest and his works is that given in the *Bibliothèque des Ecrivains de la Compagnie de Jésus*, par P. P. Augustin et Alois de Backer. Liège, 1861.

His carriage,[1] which he constructed while in China, was a small model propelled by an eolipile. It consisted of a light body on four wheels, on which was placed an eolipile[2] above a pan of burning coals; the jet from the eolipile was directed against the vanes of a wheel mounted on a vertical spindle which at its lower end was geared to the front axle of the carriage. Another orifice in the eolipile was fitted with a reed whereby the song of the nightingale was imitated. To adapt the little carriage for use in a room it was caused to move in a circular path by means of an additional wheel of larger size than those which supported the carriage, which wheel was carried on an adjustable arm. This description is derived from a rare work, *Astronomia Europæa*, published in 1687, which was issued under the direction of another Jesuit priest, and appears to have been based on works published in China in 1668. This places the construction of the carriage at a date not later than 1665, as Verbiest writes of it as having been constructed three years before.

Newton is frequently credited with having suggested the propulsion of vehicles by the reaction of an escaping jet of steam, and many of the text books contain pictures of a carriage propelled in that way, and labelled "Newton's steam carriage." The philosopher, however, is quite innocent here, and the mistake appears to have arisen in this way: a contrivance of this nature is described in Gravesande's *Natural Philosophy* which has for its sub-title *An Introduction to Sir Isaac Newton's Philosophy;* it is mentioned as an illustration of one of Newton's laws, and not as having been devised by him. A writer on the steam engine in the early part of last century took it otherwise and ascribed it to Newton. The error was pointed out in the press at the time, but so far, as in a good many other

[1] It was first brought into notice in this country by the English edition of Huc's *Christianity in China, etc.*, 1858, and by Muirhead's *Life of James Watt*, 1859. It is also described by Duhalde.

[2] The eolipile was pretty well known in the scientific circles of those days, and is to be found described in some of the books of that period.

cases, the correction has not caught up the original misstatement.

In a modified form the reaction scheme was brought before the Admiralty in 1730 by a Scotch inventor, who proposed to propel ships by firing guns from the stern. This invention was rejected, but only after experiment, as it was found that thirty barrels of gunpowder were required to move the ship ten miles; and still there are people who complain that government departments stifle invention.

The quicksilver carriage described in the *Physiologia Kircheriana Experimentalis* of J. S. Kestler, 1680, is merely a toy set in motion by mercury contained in a tube heated by a candle.

The steam carriage of Verbiest was likewise but a toy, and the same may be said of the next in chronological sequence, that invented by Denis Papin in 1698; but Papin's carriage, although a model only was constructed, is remarkable as being the first fitted with a steam engine as the term is now understood—that is to say, a machine with a cylinder and piston, and it was the first steam carriage made in Europe. This little carriage worked well enough on the floor of a room, but Papin, unlike most inventors, was not sanguine of success on the road, and he, although frequently urged on by Leibnitz, took no further steps in the matter. It is worthy of remark that the use of the steam carriage in warfare was one of its chief advantages, as they presented themselves to the mind of the Papin; by its aid, said he, infantry could be moved as quickly as cavalry, and without the necessity of additional provender.

Leibnitz himself, as well as his contemporary Huyghens, devoted some attention to the improvement of road vehicles.

During the eighteenth century the development and application of the steam engine proceeded with vigour. There was a crying need for some more powerful means than horses or men for unwatering mines, many of which were drowned out in various parts of the country. The earlier pumping machines, the invention of Savery, worked by

the direct action of steam upon a body of water, and were soon replaced by the cylinder-and-piston engine of Newcomen, which continued in use until the time of Watt's improvements. These engines were purely reciprocating in their action; being applied only for pumping purposes, there was no necessity for the production of rotary motion, and in this country at all events, whatever ideas may have been entertained by philosophers and inventors, no one seems to have set about the production of rotary motion in the steam engine and its application to purposes other than pumping before the time 1769-1771, when Nicholas Cugnot was having his steam carriages built in Paris. So that a long interval separates the models of Verbiest and Papin from the first steam carriage actually built for service. Cugnot's second and perfected carriage is still in existence, and is to be seen at the Conservatoire des Arts et Métiers, in Paris. It was built in 1770-1771 at the Royal Arsenal in Paris, by the order of the Duc de Choiseul, Minister of War, who had inspected Cugnot's first machine at work, and had been favourably impressed by it in spite of many serious defects, such as insufficient boiler power. The machine could travel for twelve or fifteen minutes at the rate of two and a quarter miles an hour, and then had to stop to generate a fresh supply of steam, and so on. By the time the new machine was completed, the Duc de Choiseul was in exile, and there being no one in power sufficiently interested, the carriage remained at the Arsenal for a long time, apparently without any trial of its capabilities being made. At least such is the received opinion, but it must be allowed that M. Pouillet, then Director of the Conservatoire, in discussing M. Morin's paper on the subject before the Académie des Sciences in 1851, held that this particular machine had been subjected to trials, and that in the course thereof it had knocked down a wall. M. Morin, however, from a careful examination of the machine, considered that it had never even been under steam, and contended that had it knocked

down a wall it would certainly have retained some marks of the encounter, which he altogether failed to discover. It is more than likely that the accounts of the first and the second machines have become confused one with the other. M. Pouillet, it may be noted, held that Cugnot before coming to Paris had made a model at Brussels.

The illustration, prepared from a photograph of the scale model of Cugnot's carriage at the South Kensington

CUGNOT'S STEAM CARRIAGE, 1770.

Museum, shows only the front part of the carriage. The little picture on the title page shows it complete to a smaller scale. The carriage is in two distinct parts; the front, mounted upon a single wheel, carries the engine and boiler, and is connected to the rear part, mounted on two wheels, by means of a vertical bolt, about which it may be turned for steering by means of a handle on a vertical spindle shown just in front of the driver's seat. The lower end of the spindle carries a pinion which engages with a

segmental rack carried by the front part or fore-carriage. The boiler looks not unlike the ordinary kitchen copper closed in at the top by a dome; it has an internal fireplace and two flues terminating in short chimneys, and is supported from the fore-carriage by iron brackets. The engine has two single acting inverted cylinders (seen immediately behind the boiler) of thirteen inches diameter, the pistons of which alternately work the front wheel by pawls and ratchet wheels. The piston rods are coupled by chains to levers mounted loosely upon the axle of the driving wheel, one on each side of it and connected together by a transverse rocking beam extending across the top of the carriage behind the cylinder. Each lever carries a reversible spring pawl, which engages with a corresponding ratchet wheel connected to the driving wheel. Thus when steam is admitted one cylinder and its piston descends, the wheel is turned through a quarter of a revolution by the corresponding pawl and ratchet, and at the same time the piston in the other cylinder is pulled to the top of its stroke by means of the rocking beam, so that it may, when the steam valve is thrown over, in its turn make a downward stroke and advance the wheel another quarter revolution. The carriage can be moved backwards by reversing the pawls. The valve is circular in section, and is formed with passages such that when in one position it opens one cylinder to the steam pipe and the other to the atmosphere and *vice versâ*. It is operated by means of a chain and rocking levers from tappets on the piston rods.

The workmanship and finish of this machine are undoubtedly good, particularly when it is remembered that it was constructed over a century and a quarter ago, when mechanical engineering was yet in its infancy. Some ingenuity is displayed, too, in the mechanism for transmitting the motion of the pistons to the wheels and for working the valve, but the general design cannot fail to impress the present-day observer as very crude. There

appears, for instance, to be no means of introducing water into the boiler except by removing the steam pipe. The fire cannot be attended to while the machine is in motion, at anyrate not when moving forward, and as there appear to be no means for starting and stopping it would be necessary to allow the carriage to run until the steam pressure fell too low to propel it further, then to fire up, taking care to clear out of the way before the steam attained sufficient power to re-start the vehicle. There is, however, a sort of brake adapted to be worked by the feet of the driver which might have been of some assistance in controlling the car.

Altogether, even if it had been tried, this carriage could have given but very poor results in practice ; it is nevertheless a most interesting machine, and it must be a matter of great satisfaction to all interested in the subject that it has been so effectually preserved.

Contemporary with Cugnot, a Swiss officer of the name of Planta was endeavouring to work out the steam-carriage problem. Nothing is known as to what his proposals were, but it is stated that when Cugnot's scheme was explained to him he retired from the field, admitting that his own was inferior.

Ten years later a steam carriage made by one Dallery was to be seen at work in the streets of Amiens, and in 1790 the same vehicle appears to have been exhibited in Paris. The inventor obtained a patent in 1803 "pour un bateau à hélice et une voiture à vapeur marchant sur routes ordinaires," in the specification pertaining to which is shown a curious boat-shaped vehicle driven by a steam engine. The original invention of the multitubular boiler is claimed for Dallery, and it is indeed stated that his carriage of 1780 was fitted with that form of steam generator.

It will be seen, then, that the idea of applying the steam engine to the propulsion of road carriages may be said to be contemporaneous with the birth itself of that motor,

and indeed the idea is one that might readily occur to any one considering the matter in the light of the numerous attempts which were being made to supersede horses. Later on Watt himself writes that his attention was first directed to the subject of the steam engine in 1759 by Dr Robison, then a student in the University of Glasgow, who had specially suggested the application of the engine to purposes of locomotion. Watt, however, never constructed a steam carriage, and never looked upon the project with favour. In 1769, writing to his friend Dr Small in reference to the project of a London linen draper named Moore, of whom more hereafter, Watt says, "If linen draper Moore does not use my engine to drive his chaises, he can't drive them by steam. If he does I will stop him." This seems to have been the keynote of Watt's position throughout; he had no belief in the possibility of steam locomotion on common roads, but in spite of that, hoped to prevent others from entering upon it. In the specification of his patent, dated 1784, there is included a description of a steam carriage which, in a letter to his partner Boulton, he admits to be very defective "and can only serve to keep other people from similar patents." The description of the steam carriage is certainly crude. The boiler was to be of *wood*, or of thin metal surrounded by strengthening hoops, and preferably of cylindrical or globular form, with the furnace inside and surrounded by water. The engine was to be double-acting, and either non-condensing or condensing by means of an air-cooled surface condenser, and two-speed gearing might be employed.

In other letters to Boulton in the same year he elaborates his ideas to some extent, goes into minute calculations as to the size of engine required, states that the engine may be a beam engine or a direct-acting vertical engine, and that it should be placed behind the boiler, to act upon the rear wheels of the vehicle He mentions copper as the material for the boiler, and points out the advantage of

coke as fuel. "The shaking of the carriage would," he thought, "supersede the necessity of poking the fire." It appears that Watt's first idea was to use a vertical engine, driving the axle by means of a rack and pinion. He also contemplated the use of a rotary engine, but doubted the possibility of that type of motor. It is not clear why he took this particular moment for making the steam carriage the subject of a patent; perhaps his assistant, William Murdock, had already begun his experiments in that direction. Two years later, when the partners were greatly dismayed at Murdock's inclination to proceed with his project, Watt wrote, "I have one of some size under hand, and am resolved to try if God will work a miracle in favour of these carriages"; and again, "I believe I shall make some experiments on them soon, but have small hopes of their ever becoming useful." But even if, as the letters suggest, Watt had begun the construction of a steam carriage he certainly never finished it.

William Murdock, who was at that time acting for the firm of Boulton & Watt in Cornwall, made a model steam carriage in 1784, which seems beyond doubt to be the first locomotive engine made in this country. It is interesting to add that this little machine is still in existence, in the possession of Messrs Tangye, and that it is still in working order. It is so simple in construction and is so clearly shown in the illustration that a very brief description will suffice. The body, a plain flat board, mounted on three wheels, carries the boiler and engine at the rear; the boiler is rectangular and of copper, it is traversed by an inclined flue and adapted to be heated by a spirit lamp; the engine has a cylinder three-quarters of an inch in diameter, which is placed in the boiler; the piston rod is coupled to a rocking beam, from which a connecting rod descends to the cranked axle of the rear wheels; one of these wheels is loose to allow the carriage to turn; the front wheel is mounted in a swivel so that it may be turned for steering. The valve by which the steam is admitted to and released from the cylinder is

moved up and down by means of the rocking beam and a tappet rod; it is of the type now known as the "piston valve." The application of the crank for converting the reciprocating motion of a steam-engine piston into rotary motion had been patented by Pickard in 1780. This is the

MURDOCK'S MODEL STEAM CARRIAGE, 1784.

first instance of its use in connection with a locomotive carriage.

There is a quaint story of a trial which Murdock made with his carriage which is worth repeating:—

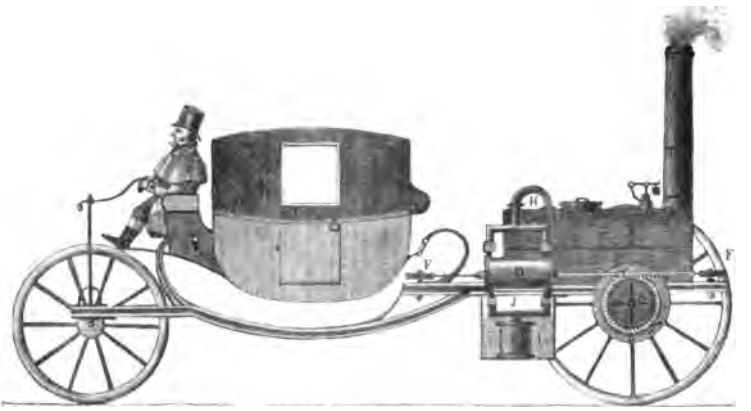
"At the time Mr Murdock was making his experiments with his locomotive engine he greatly alarmed the clergyman of the parish of Redruth. One night, after returning from his duties at the mine, he wished to put to the test the power of his engine, and as railroads were then unknown he had recourse to the walk leading to the church, situate about a mile from the town. This was rather

narrow, but kept rolled like a garden walk, and bounded on each side by high edges. The night was dark, and he alone sallied out with his engine, lighted the fire or lamp under the boiler, and off started the locomotive with the inventor in full chase after it. Shortly after he heard distant despairlike shouting; it was too dark to perceive objects, but he soon found that the cries for assistance proceeded from the worthy pastor, who, going into the town on business, was met in the lonely road by the fiery monster, whom he subsequently declared he took to be the evil one *in propriâ personâ*."[1]

Murdock allowed the matter to drop at this time, but two years later—possibly through having heard of the attempts of Symington and others—he again took it up and caused his employers to be informed that he had made a small steam carriage which answered amazingly. This was probably the original carriage, which no doubt had been left in an incomplete or imperfect state after the first trial, so graphically alluded to in connection with the parson of Redruth, and had now received the finishing touches. Boulton and Watt however considered it would never do for their most capable man to spend time and money in hunting shadows, and determined to try and arrest any further action in the matter on his part. Accordingly Boulton started for Cornwall. He had got as far as Exeter when he met a coach, in which was Murdock on his way to London to show his model and obtain a patent. Boulton's persuasion succeeded in making him turn back, and the partners then made an effort to keep Murdock so fully engaged in connection with mining work that he should have no time to dwell upon the steam carriage. This was probably an uncongenial task for Boulton, who admits that the carriage is a pretty working model, but although at first sight it appears a matter for regret that Watt and his partner placed so many obstacles in Murdock's path, there is no doubt that it left him free to pursue objects which

[1] Buckle, *Proceedings of the Institution of Mechanical Engineers*, 1850.

were more ripe for treatment; a practical success in the matter of steam carriages was altogether out of the question on the roads of those days. Murdock appears at this time to have had some scheme for utilising the momentum acquired in going down hill for the purpose of assisting the ascent of the carriage up hill, but beyond making occasional experiments with his little model, which he at times worked by a supply of coal gas stored in a bladder, instead of a lamp, he appears to have dropped the steam-



A. Pinion. B. Ratchet Wheel. C. Rack. D. Cylinder. E. Boiler. F. Chains for connecting the Racks. H. Steam Pipe. G. I. J. Condenser.

SYMINGTON'S MODEL STEAM CARRIAGE, 1786.

carriage project entirely. Later on in life he is said to have made some experiments in the application of compressed air to carriages.

At about the same time as Murdock was making his model steam carriage in Cornwall another was being made up in the wilds of Lanarkshire by William Symington, the engineer of the Wanlockhead Mines, whose name is best known in connection with the early history of steam navigation. Symington's model was exhibited at Edinburgh in 1786; and it worked very successfully, but the inventor was deterred from proceeding further in the

matter by the consideration of the state of the roads in Scotland, and of the difficulty in obtaining supplies of fuel and water. He was of opinion, too, that the steam engine could be more readily adapted to boats than to road vehicles, and accordingly turned his attention to steam navigation. Symington's model was worked by a single-cylinder condensing engine, which was connected to the axle of the rear wheels by racks and pinions. On one side of the machine was a rack, connected directly to the piston rod of the engine, which engaged a pinion loose on the axle but adapted to drive it when moving in one direction by means of a pawl and ratchet wheel. Another rack on the opposite side of the machine was connected to the first by chains passing over pulleys and geared with another pinion connected to the axle in the same way as the former. Both strokes of the engine, acting alternately upon opposite ends of the axle, were thus utilised to drive the engine forward.

Richard Lovel Edgeworth, the father of Maria Edgeworth, was in his younger days an ardent advocate of the application of steam power to locomotion, but it does not appear that he ever attempted to construct a motor carriage.

Another steam-carriage enthusiast of the period was Erasmus Darwin, the grandfather of Charles Darwin, who was in practice as a physician at Lichfield. Writing to Boulton in 1765, he enumerates what he considers to be the desiderata of the "fiery chariot," and outlines a scheme of construction, but this is very crude and may be omitted here. The forecast of the application of steam to purposes of locomotion generally in his poem "The Botanic Garden" is fairly well known to students of the subject:—

> "Soon shall thy arm, unconquered steam, afar
> Drag the slow barge, or drive the rapid car;
> On, on, wide-waving wings expanded bear
> The flying chariot through the fields of air,

Fair crews triumphant, leaning from above,
Shall wave their fluttering kerchiefs as they move,
Or warrior bands alarm the gaping crowds,
And armies shrink beneath the shadowy cloud."

Francis Moore, a London linen draper, made a considerable stir with a motor-car project in the year 1769, and he must have been very sanguine of success—that is, if any weight is to be attached to the statement in one of the papers of the day, that the ingenious inventor had already sold all his own horses and that many of his friends had done likewise, "because the price of that noble and useful animal will be so affected by his new invention that their value will not be one-fourth of what it is at present."

James Watt refers to Moore's project in a letter dated April 28, 1769, "If linen draper Moore does not use my engine to drive his chaises he can't drive them by steam. If he does I will stop them. I suppose by the rapidity of his progress and puffing he is too volatile to be dangerous. . . . Here I work five or more years contriving an engine, and Mr Moore hears of it, is more *éveillé*, gets three patents at once, publishes himself in the newspapers, hires 2000 men, sets them to work for the whole world in St George's Fields, gets a fortune at once, and prosecutes me for using my own invention."

Evidently if he could treat it in this jocular strain Watt did not think very highly of the scheme. Moore did obtain two patents for motor cars in this year. The first was for "machines or engines made of wood, iron, brass, copper, or other metal, to be wrought or put in motion by fire, water or air, with a small assistance of horses or manual labour, which will be found very useful in agriculture, carriage of persons, goods, etc.," and the second was "constructed upon peculiar principles capable of being wrought or put in motion by force or power without being drawn by horses, or any other beasts or cattle, etc." But in each case a condition of the grant of

the patent, viz., that a description of the invention should be filed within a prescribed time was not complied with, so that the patents became void. This seems to indicate that even if Moore had begun the construction of steam carriages, he very soon found the difficulties such that he could not cope with. On the other hand, *The Gentleman's Magazine* of 21st July 1769 states that "Mr Moore, the

MOORE'S CARRIAGE "TO GO WITHOUT HORSES," 1771.

ingenious contriver of the carriage to travel without horses, waited upon his Majesty at Richmond with one of them, who was graciously pleased to express his approbation of it," and there are frequent references in the journals of the period to Mr Moore's carriage for travelling without horses.

It is well authenicated, however, that Moore did not confine his attention to steam carriages, and that he carried into execution certain projects in connection with horse-drawn vehicles, and these, possibly because he found that one horse

could, with his new carriage, do the work of two with one of the usual make of that period, he termed "carriages to go without horses"; and a print of his carriage, dated 1771, from which the accompanying illustration is reproduced, has for its title "Mr Moore's new invented Machine for Travelling without Horses." There is no question as to the presence of the horse here, and a journal of the same year refers explicitly to "the coach Mr Moore had invented on a new principle to be drawn by one horse," and there can be no doubt that it was a carriage of this description that was exhibited to the King. Its essential features are the large size of the wheels, the position of the driver, and the method of suspending the body. Moore made a mail cart for the General Post Office on the same lines, with wheels eight feet eight inches high. The coal carts which he made are stated to have had wheels as much as fifteen feet high; with them two horses could haul twice as much coal as three with the ordinary carts, at least so the accounts go.

Following Symington we have an inventor, of whom very little is known—Robert Fourness of Elland, Halifax—who, in conjunction with James Ashworth, obtained, in 1788, a patent for a road locomotive intended for drawing other vehicles. It was proposed to use a three-cylinder vertical non-condensing engine geared to the rear axle of the vehicle by means of cogwheels, and the exhaust steam was to be turned into the water tank to warm up the feed water. It is not clear whether this invention was ever carried out in practice, but a drawing which appeared some years ago in one of the engineering journals appears to have been prepared from a model. There is some reason for thinking that Fourness and Ashworth, like Symington, relinquished the problem of the steam road vehicle for that of steam navigation.

Oliver Evans, a celebrated American engineer and millwright, although he never proceeded so far as to construct a steam carriage, was a firm believer in their practicability. It appears that it was during his apprentice-

ship, sometime about the year 1772, that he first turned his attention to the propulsion of road vehicles. After considering the application of the wind as a motive power, treadles, cranks, etc, worked by men, he was about to relinquish the problem for want of a suitable motor, when he was informed of an experiment made in a neighbouring smithy. Some boys had, for amusement, after plugging up the touch-hole, charged a gun barrel with water, rammed in a wad and placed the breech end in a fire, with the result that after a little while the gun had discharged itself as if loaded with gunpowder. From this experiment Evans evolved the idea of a high-pressure steam engine which he considered would be specially suitable for road carriages. In the course of his life he constructed a number of steam engines, but his many attempts to induce capitalists to embark upon the steam-carriage project were fruitless. At last, in 1804, he seized an opportunity of demonstrating that his plan was not entirely visionary by fitting up a steam dredger, which he had made for cleansing the harbour of Philadelphia, with means for self-propulsion from his works to the waterside, a distance of one and a half miles. To give Evans' own account of the experiment: "This was a fine opportunity to show the public that my engine could propel both land and water carriages, and I resolved to do it. When the work was finished, I put wheels under it; and though it was equal in weight to two hundred barrels of flour, and the wheels were fixed on wooden axletrees for this temporary purpose, and in a very rough manner, and attended with great friction of course, yet, with this small engine, I transported my great burthen to the Schuylkill with ease; and, when it was launched into the water, I fixed a paddle-wheel at the stern, and drove it down the Schuylkill to the Delaware, and up the Delaware to the city, leaving all the vessels going up behind me at least half way, the wind being ahead."

How visionary his project had been considered is clear from the fact that when in 1786 he petitioned the Legislature of Pennsylvania for the sole right to use his

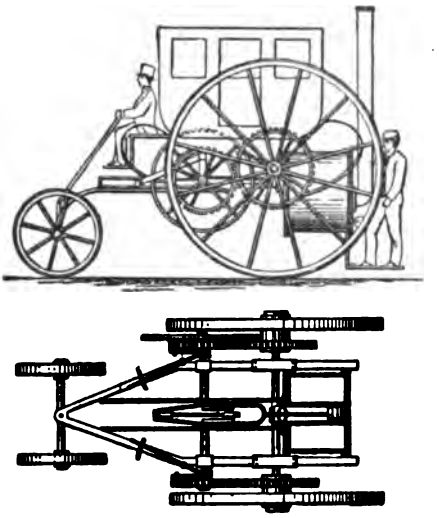
steam wagons in that state he was thought insane. The Marylanders probably thought the same, but to the representation that the protection desired could at anyrate do no harm, and might lead to something useful, he was granted the sole right to make and use steam wagons in the state of Maryland for fourteen years from 1787.

Another American inventor, Nathan Read, conceived the idea of a steam carriage in 1788-1789. In 1790 he applied to Congress for a patent for this invention, and although his application fell through, the description and drawing prepared in connection with it have fortunately been preserved.[1] Read proposed to use a multitubular boiler, a patent for which he obtained in 1791, and this in itself was a most important step in the development of the steam carriage, for without some such construction it is absolutely impossible to secure sufficient steam generating power within the limits of weight allowable in such vehicles. Read's boiler, however, remained in obscurity until comparatively recent times, and his invention appears to have had no bearing upon the development of the steam carriage. It was proposed to use two double-acting engines, each working one of the rear wheels by racks and a pinion—that is to say, to have one engine for each wheel, so that either could be used separately to cause the carriage to turn to one side or the other. With the idea of assisting the motion of the carriage, the exhaust steam was to be discharged backwards.

Trevithick, perhaps the greatest inventive genius that has ever appeared in this country and the man who of all others is justly entitled to be styled the "father of the locomotive," commenced his labours with a number of attempts at steam carriages. He was no doubt aware that Murdock had made a model of such a carriage, and may have been acquainted with its construction; at anyrate, in

[1] They are reproduced, together with accounts of Reed's other inventions, in D. Read's *Nathan Read: his Invention of the Multitubular Boiler, etc.* New York, 1870.

1796 and the following years, he constructed several models himself. One of them is still in existence, and may be seen at the South Kensington Museum. It is mounted on three wheels, and has a horizontal cylindrical boiler in which is to be remarked the curious feature that heat is supplied by means of a heated iron, just as in a box smoothing iron. The engine is vertical with the cylinder placed partly in the boiler. The rear wheels carry crank pins, which are coupled by side rods to a cross-head secured to the upper end of the piston rod. A fly wheel mounted on a stud axle is connected to one of the wheels by toothed gearing.



TREVITHICK'S CARRIAGE, 1802.

Trevithick was so satisfied with the working of his models that he proceeded to the construction of a large carriage. This was completed towards the end of 1801, and on the Christmas Eve of that year made its trial trip, which has been vividly described by a resident of Camborne :—

"In the year 1801, upon Christmas Eve, towards evening, Captain Dick (Trevithick) got up steam out in the highroad, just outside the shop at the Weith. When we see'd that Captain Dick was a-going to turn on steam, we jumped up, as many as could—maybe seven or eight of us. 'Twas a stiffish hill going from the Weith up to Camborne beacon, but she went up like a little bird. When she had gone about a quarter of a mile, there was a roughish piece of road, covered with loose stones. She didn't go

quite so fast, and as it was a flood of rain, and we were very squeezed together, I jumped off. She was going faster than I could walk, and went on up the hill about a quarter or half a mile further, when they turned her, and came back to the shop."

It may be well to explain that Trevithick was a Cornish mining captain, and that he had nothing to do with the sea.

In 1802 Trevithick, in conjunction with a relative, Andrew Vivian, took out a patent, covering, among other things, his steam carriage. The specification describes an engine with a single horizontal cylinder fixed in a horizontal boiler, which is shown underneath a carriage of ordinary design. The piston rod is forked, to pass over the crank shaft, which it works by a return connecting rod. Gearing with spur wheels on the naves of the main road wheels are loose spur wheels on the ends of the crank shaft, to which they are connected by arms on the latter engaging with pins on the former. The said arms may be moved in and out of gear by hand levers.

It is interesting to note that Trevithick contemplated the use of a change-speed gear with sliding wheels such as is now used. After describing the drawings the specification proceeds.—

". . . It is also to be noticed that in certain cases we make the external periphery of the road wheels uneven by projecting heads of nails or bolts, or cross grooves, or fittings to railroads, when required, and that in cases of hard pull we cause a lever bolt or claw to project through the rim of one or both of the said wheels, so as to take hold of the ground; but that in general the ordinary structure or figure of the external surface of these wheels will be found to answer the intended purpose. And, moreover, we do observe and declare that the power of the engine with regard to its convenient application to the carriage may be varied by changing the relative velocity of rotation of the road wheels, compared with that of the

crank axis, by shifting the gears or toothed wheels for others of different sizes properly adapted to each other. . . . We do occasionally use bellows to excite the fire, and the said bellows are worked by the piston rod or crank."

In 1802 a locomotive was being built according to Trevithick's plans at Coalbrookdale, and in 1803 an engine made very much on the lines of the specification was sent to London, where it was attached to a coach, and run along the streets with a fair amount of success, although it is recorded that on one occasion it tore down a garden wall; it also came in for volleys of cabbage stumps, rotten onions and eggs from coachmen and others.

Trevithick, however, soon relinquished his attempts at locomotion upon common roads, and turned his attention to railways, and in 1804 he completed the tramway locomotive at Penydarren, near Merthyr Tydvil; in the same year he was having an engine built at Gateshead-on-Tyne. Four years later he was again in London, running his locomotive on a circular railway upon the ground now forming Euston Square; but he met with so little encouragement that he became thoroughly disgusted with the subject, and in 1809 he appears to have refused an order for a locomotive, stating that he was "engaged in other pursuits, and having declined the business could render no assistance."

After Trevithick's time the idea got abroad that the adhesion of plain wheels was not sufficient to propel an engine. Accordingly, in 1812, we find Blenkinsop laying down his rack railway near Leeds, and, what is more closely connected with the present subject, in 1813, we have Brunton with his "Mechanical Traveller." In this most curious piece of engineering the engine was propelled by a pair of legs, to which was given a motion resembling walking. The piston rod in its outward movement forced out one leg and foot, which pushed behind, but as the foot was fixed against the ground it could not move back; the

engine was therefore caused to advance. At the same time the movement of the piston rod, reversed by means of a pinion and racks upon the top of the boiler, pulled in the other foot, which was lifted clear of the ground by means of leather straps and levers. Upon the reversal of the movement of the piston the second leg acted as the pusher, and the first was drawn in. The machine was employed at the Butterly Ironworks, but came to an untimely end in consequence of the boiler exploding when at work.

CHAPTER VI

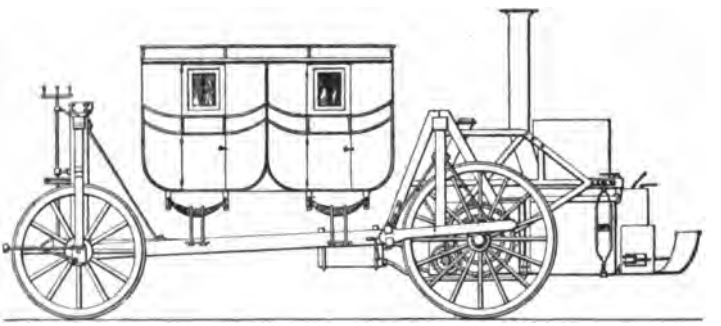
THE STEAM-CARRIAGE BOOM, 1821-1840

THE period from 1821 to 1840 was one of most intense activity in steam-carriage building, and it forms the most important and extensive chapter in the history of steam locomotion on the road. The importance of the movement in this period may be judged from the fact that in December 1833 there were already built, or in course of construction, in London alone, as many as twenty drags and carriages. Another indication is to be found in the number of companies formed *or projected* to work lines of steam coaches. Mention may be made of the London and Birmingham Steam Carriage Company, 1832; the Paddington and London Steam Carriage Company, 1832; Heaton's Steam Carriage Company, 1833; the London, Holyhead and Liverpool Steam Carriage and Road Company, 1834; the Steam Carriage Company of Scotland, 1834; the Hibernian Steam Coach Company, 1834; and the Steam Carriage and Waggon Company, 1838.

Evidence of the public interest in the subject is afforded by the circumstance that Alexander Gordon's *Treatise upon Elemental Locomotion* ran into a third edition in the course of four years, and that the author thereof brought out two special journals, *i.e.*, the *Journal of Elemental Locomotion*, in 1832, and the *Journal of Steam Transport and Husbandry*, in 1833. Gordon seems to have been afraid that the steam carriage people would amass too much wealth, so in the latter of these journals he devoted an article to a "Proposal for Appropriating for the use

of the Public Purse the Vast Revenue that will Arise Annually from Internal Elemental Transit."

The movement may be said to have commenced with the attempt of Julius Griffiths[1] of Brompton, who in 1821-1822 had a carriage built by Bramah, the well-known engineer and lockmaker. The advent of this carriage was announced with a great flourish of trumpets. In view of the "universal importance" of the invention it was patented



GRIFFITHS' STEAM CARRIAGE, 1822.

not only in England but in Austria and America also. The carriage, which was being built, was intended to carry three tons of merchandise at five miles an hour, and at a saving of twenty-five per cent. as compared with horses. But in spite of the best workmanship of the day it was a complete failure. This carriage had a very long wheel base, and the engine, boiler, etc., were hung over the rear axle by means of a spring suspension. The steam was generated in a water-tube boiler, composed of a number of rows of horizontal tubes which extended across the fire-box, and passed out through the sides thereof into vertical connecting boxes. A two-cylinder engine was used and

[1] Griffiths was a fairly well-known man in literary circles in his day; he had distinguished himself by his travels through Europe and the East; he had made his way down the Tigris and the Euphrates, and visited India, Ceylon and Sumatra. How he came to turn his attention to the steam carriage is not clear, but the invention of the carriage was partly that of a foreigner named Artzberger.

a condenser was provided. It is interesting to note that the condenser was cooled by air; it consisted of a number of flattened tubes of thin metal. The boiler seems to have been the greatest source of trouble; it was found impossible to retain the water in the lowest tubes.

David Gordon, whose name is mentioned in conjunction with that of Murdock in connection with com-

GORDON'S STEAM CARRIAGE, 1824.

pressed-air carriages, was labouring at steam-carriage projects at about the same time as Griffiths, and it does not appear that he met with greater success. One of his ideas was to place the engine inside a sort of magnified squirrel cage in the form of a drum nine feet in diameter; the wheels of the engine were toothed and engaged with correspondingly toothed rings inside the drum, so that it was constantly striving to climb up therein, with the result that the drum rolled forwards upon the road. The engine pushed a carriage in front of it by means of side rods.

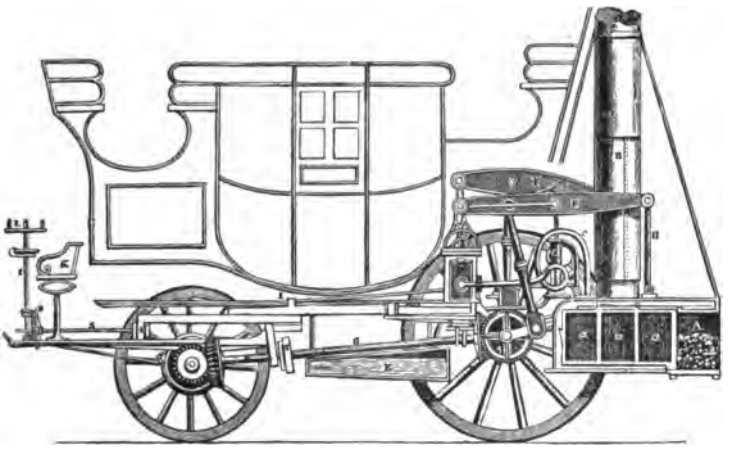
Gordon's next scheme, patented in 1824, is shown in the drawing. It was a steam coach propelled by means of legs, a plan which had been tried long before by Baines in a pedomotive carriage and by Brunton in a locomotive, and was tried afterwards by Gurney. Hebert, in his *Encyclopædia*, 1840, describes the action in the following terms:—

"In the fore part of the carriage were placed the steam engines, consisting of two brass cylinders, in a horizontal position, but vibrating upon trunnions: the piston rods of these engines gave motion to an eight-throw crank, two in the middle for the cylinders, and three on each side, to which were attached the propellers; by the revolution of the crank, these propellers or legs were successively forced outwards, with the feet of each against the ground in a backward direction, and were immediately afterwards lifted from the ground by the revolution of another crank, parallel to the former, and situated at a proper distance from it on the same frame. The propelling rods were formed of iron gas tubes, filled with wood, to combine lightness with strength. To the lower ends of these propelling rods were attached the feet, of the form of segments of circles, and made on their under side like a short and very stiff brush of whalebone, supported by intermixed iron teeth, to take effect in case the whalebone failed. These feet pressed against the ground in regular succession, by a kind of rolling, circular motion, without digging it up; and it must be acknowledged that Mr Gordon, in these contrivances, succeeded in avoiding the injurious effect upon the road that would otherwise have been caused by this mode of propelling. The guide had the power of lifting these legs off the ground at pleasure, so that, in going downhill, when the gravity was sufficient for propulsion, nothing but a brake was put into requisition to retard the motion if necessary. If the carriage was proceeding upon a level the lifting of the propellers was equivalent to the subtraction of the power, and soon brought it to a stoppage; and in making turns in a road the guide has only to lift the

propellers on one side of the carriage, and allow the others to operate alone, until the curve is traversed."

From Hebert's account it appears that a carriage was made on this plan, and that it worked successfully, but that the engine power was too low to get up any speed.

The movement was not confined to England, for in 1824 we find two Scotch inventors, Burstall and Hill, of Leith, at work upon the subject. Their original project is shown in the drawing. They drove the front axle from the rear axle



BURSTALL AND HILL'S STEAM CARRIAGE, 1824.

by bevel gearing and a longitudinal coupling shaft 6, into the length of which a universal joint 7 was introduced The wheels were connected to the axles by pawls and ratchets, so that they were free to over-run. The water was forced from the tank E to the boiler A by air pressure, produced by a pump *e*. A model of this carriage in a modified form was exhibited at work in Edinburgh and London. It had an additional pair of wheels to support the boiler, which was of a different construction to that shown.

The carriage shown on the next page was the invention of W. H. James, who was certainly a man of considerable ingenuity, but constantly in difficulties in carrying his plans

into execution in consequence of what a writer of the period terms "a deficiency of that metallic medium which is indispensable to the successful culture of steam carriages." James had turned his attention to the subject in 1824, but it was not until four or five years later, when he got Sir James Anderson for a partner, that his first carriage was built. Its principal features were a water-tube boiler, small engines, using high-pressure steam, and separate engines to each driving wheel, the stop valves of which engines were controlled by the steering gear, so that when the carriage was moving in a curve more steam was passed to the engine of the more rapidly moving wheel than to the other. This carriage is reported to have travelled in 1829 over a rough gravel road in Epping Forest at the rate of twelve to fifteen miles per hour, carrying fifteen passengers, and the carriage itself weighed over three tons. Considerable difficulty was found, however, with the boiler. The tubes were made of ordinary gas piping and continually gave way at the seams. Another carriage intended as a drag was then built. This had oscillating engines and a feed-water heater heated by the exhaust steam. Great things were promised with this engine, but nothing was done with it, possibly because Sir James Anderson got into pecuniary difficulties himself. James continued for some years to invent improvements in steam carriages, but he was never in a position to carry them into effect.

JAMES AND ANDERSON'S STEAM CARRIAGE, 1829.

Anderson, however, nine years later, came out as an inventor himself with a new boiler. The Steam Carriage

and Waggon Company was formed to build carriages on his plans, and a number were made in the years 1839 and 1840 in Dublin and Manchester, and carriages were to be seen at work in both places. There are glowing accounts of the successes obtained at experimental runs, but the scheme very soon fell through.

About the year 1825 Henry Peto constructed a steam coach propelled by a beam engine and provided with a two-speed gear. It was found too unwieldy and heavy for road traffic, and appears not to have been brought into use.

In the same year, 1825, T. W. Parker, in America, is stated to have made a large model steam carriage mounted on three wheels eight feet in diameter and propelled by a two-cylinder engine.

James Nasmyth of steam-hammer fame, after having made a model, constructed a full-size steam carriage about 1827. It worked very well, carried eight passengers, but after being used experimentally for a few months was broken up.

Dr Harland, of Scarborough, at about the same date also made a model. He commenced the construction of a carriage, but found the professional demands on his time too great to be able to complete it.

There were other inventors busy constructing carriages at this time, but their labours do not call for special note, and we may pass on to the man who made the most striking figure in the eye of the public in this period—Sir Goldsworthy Gurney.

Gurney's Steam Carriages

Gurney[1] began his experiments with steam carriages in 1823, just after Griffiths had abandoned the subject, but

[1] Goldsworthy Gurney was born at Padstow, in Cornwall, in 1793; he was educated as a doctor and afterwards set up in practice as a surgeon at Wadebridge, where he married in 1814. Six years later he moved to London, where he practised as a surgeon, delivered lectures on chemistry, etc., and was soon moving in the highest scientific circles of the day. He was the inventor of the oxy-hydrogen blowpipe, the limelight, and the steam jet for ventilating mines, etc. In 1852 he arranged the lighting and ventilating systems of the new Houses of Parliament, which he continued to superintend until 1863, when he was knighted. He died in 1875.

there was still a considerable amount of public discussion going on in reference thereto, and Gurney no doubt recalled to mind the experiments which he had seen carried out in his schooldays with Trevithick's carriage. In 1825 or 1826 he had completed a carriage, and in 1827 he brought out his "new improved steam coach," the advent of which was heralded with a great flourish of trumpets. Thus, in *The Mirror* of December 15, 1827, from which our illustration

GURNEY'S STEAM COACH, 1827.

is reproduced, it is referred to as an extraordinary invention on a new principle; and in deference to the general scepticism on the point, *The Mirror* proceeds to explain that the boiler is perfectly safe, and that even if it did burst there was not the most distant chance of injury to the passengers, because it was "constructed upon philosophical principles and upon a plan totally different from anything previously in use." To explain the drawing *The Mirror* gave a key to the reference numerals thereon,

which, as being rather quaintly worded, while still giving a fair explanation of the construction of the carriage, will be made use of in a somewhat abridged form.

Explanation of the References.

1. The Guide and Engineer, to whom the whole management of the machinery and conduct of the carriage is intrusted. Besides this man, a guard will be employed.
2. The Handle which guides the Pole and Pilot Wheels.
3. The Pilot Wheels.
4. The Pole.
5. The Fore Boot, for luggage.
6. The "Throttle Valve" of the main steam pipe, which, by means of the handle, is opened or closed at pleasure, the power of the steam and the progress of the carriage being thereby regulated from one to ten or twenty miles per hour.
7. The Tank for Water, running from end to end, and the full breadth of the carriage; it will contain sixty gallons of water.
8. The Carriage . . . six inside passengers.
9. Outside Passengers, fifteen.
10. The Hind Boot, containing the Boiler and Furnace. The Boiler is incased with sheet iron . . . The pipes extend from the cylindrical reservoir of water at the bottom to the cylindrical chamber for steam at the top, forming a succession of lines something like a horse shoe turned edgeways. The steam enters the "separators" through large pipes, which are observable on the Plan.
11. "Separators" in which the steam is separated from the water.
12. The Pump, by which the water is pumped, from the tank, by means of a flexible hose, to the reservoir, communicating with the boiler.
13. The Main Steam Pipe, descending from the "separators," and proceeding in a direct line under the

body of the coach to the "Throttle Valve" (No. 6), and thence, under the tank, to the cylinders (No. 16), from which the pistons work.

14. Flues of the Furnace, four in number, from which there is no smoke, coke and charcoal only being used.

15. The Perches, of which there are three, conjoined, to support the machinery.

16. The Cylinders. There is one between each perch.

17. Valve Motion admitting steam alternately to each side of the pistons.

18. Cranks, operating on the axle: at the end of the axle are crotches (No. 21), which, as the axle turns round, catch projecting pieces of iron on the boxes of the wheels, and give them the rotatory motion. The hind wheels only are thus operated upon.

19. Propellers, which, as the carriage ascends a hill, are set in motion, and move like the hind legs of a horse, catching the ground, and then forcing the machine forward, increasing the rapidity of its motion, and assisting the steam power.

20. The Drag (brake), which is applied to increase the friction on the wheel in going down a hill. This is also assisted by diminishing the pressure of the steam—or, if necessary—inverting the motion of the wheels.

21. The Clutch, by which the wheel is sent round.

Gurney used a water-tube boiler, consisting of two horizontal drums which extended one above the other across the coach—their ends are to be seen at the rear of the coach in the drawing—and were connected by vertical pipes at each end and by rows of tubes, bent somewhat into the form of horseshoes; these bent tubes were at first made of gas tubing, but this was found to open out at the seams, and lap-welded iron tubes were afterwards used. They extended towards the front of the carriage, and their upper limbs entered the top, and their lower limbs the bottom drum; the upper surface of the lower limbs formed the fire-grate, which was supplied with fuel through a

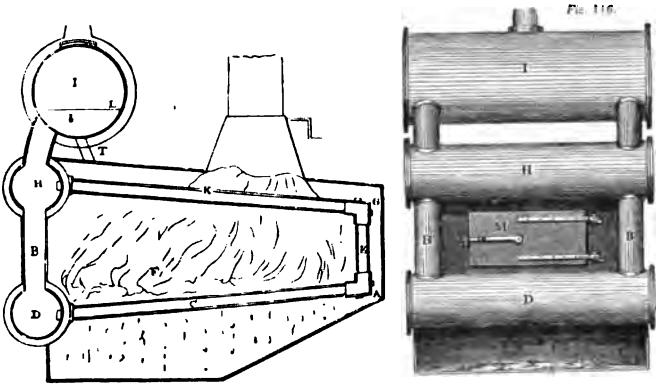
doorway in the end of the enclosing chamber. The vertical steam drums or "separators," which form such a striking feature at the rear of the coach, were connected to the top drum of the boiler. Any water carried over by the steam fell to the bottoms thereof, which were in communication with the bottom drum of the boiler. The steam pipe led from the upper ends of the steam drums to the front of the carriage, where it was provided with a stop or "throttle" valve within easy reach of the driver, and thence down to the cylinders. The chimneys were immense affairs, and are to be seen in front of the steam drums in the drawing of the coach. In the drags, subsequently made, a single horizontal drum mounted above the top drum of the boiler was used as a steam receiver. In an earlier construction the steam drums were partly enclosed in the chimneys, and a fan, driven by a separate engine, was used to create a draught. In the coach under consideration the escaping steam was relied on for this purpose. Gurney, it should be noted, allowed the steam from the engine to escape into an exhaust box or silencer, so that the draught was not produced by a blast pipe, as in the locomotive. Fusible plugs were used in the boilers.

It will be observed that this coach is fitted not only with driven rear wheels, but with propelling legs as well. Gurney had seen the wheels of Trevithick's carriage turn round and fail to grip the road, and had come to the conclusion that plain wheels did not possess sufficient adhesion. Accordingly his first carriage was propelled entirely by means of legs; then he tried driving by the wheels, retaining the legs for use in emergencies; but experience convinced him that, with the engine properly handled, the wheels were always quite sufficient to transmit the driving force, so in the end the propellers were removed altogether. One wheel only was driven, the other usually ran loose, but could be coupled to the axle when desired.

It is interesting to note how in succeeding carriages

Gurney contrived to reduce the weight; starting with four tons, it was first brought down to two tons, and then to thirty-five cwts., for the same power in each case; this weight was that of the carriage empty and without fuel and water.

In an account of a run made in this carriage, from Gurney's workshop near Regent's Park, out along the Edgware Road, it appears that the first six miles was done in thirty-five minutes, and that a stop was then made to take in a fresh supply of water; the slowest pace



D, H. Lower and Upper Drums, connected by Pipes B.
C, K. Lower and Upper Ranges of Tubes, connected by Tubes E.
I. Steam Drum.
F. Fire.
M. Fire Door.

GURNEY'S BOILER (FINAL FORM).

up hill was over five miles an hour; at other parts of the journey a speed of fourteen to fifteen miles an hour was attained, although the roads were heavy.

Later on in the year 1828 Gurney took his carriage to South Wales, and either this or a succeeding carriage was sold to Crawshay, the great ironmaster, and fitted up as a tramway locomotive. It seems to have given satisfaction, for, writing in March 1830, Mr Crawshay stated that the engine weighed thirty cwts. and could draw twenty tons after it on a cast-iron way; it got

up steam in less than five minutes and went three miles in thirty-nine minutes. Two years later the same gentleman reported very favourably of the performance of the engine, and stated that it had required but trifling repairs.

By the year 1829 it would appear that Gurney had turned his attention to the use of a separate drag or "tractor" adapted to haul an ordinary carriage. This seems clear from the "Minutes of a journey from London to Bath with Mr Gurney's steam carriage, July 28, 1829 . . . kept at the request of the Quartermaster-General" by one Dady, who describes himself as Mr Gurney's confidential manager. The entire party consisted of fourteen persons; of these there were three on the steam carriage and five in the carriage which it hauled, the others rode in horse carriages. It is reasonable to suppose that had the steam carriage been of the same construction as that of 1827, capable of carrying twenty-three persons, that separate carriages would not have been used, particularly not horse-drawn carriages. It is very likely that the vehicle in question was the same as, or similar to, that shown in the next drawing, which is "a sketch of Mr Gurney's new steam carriage, as it appeared at Hounslow in 1831, with a barouche attached, containing the Duke of Wellington and other persons of distinction."

On the journey to Bath alluded to above the speed averaged twelve miles per hour as far as Melksham, where—

"There happened to be a fair, and an immense crowd of people had collected together. The mass was so dense that it was impossible to move the carriage through them but at a very slow pace. The people were principally composed of agricultural labourers and the manufacturers of the district. They considered the carriage injurious to their interests; they said it was a carriage driven by machinery. A cry of 'Down with machinery' was raised in different places, and an attack of a very serious nature commenced upon the carriage and our whole party; some were seriously injured—Mr Bailey, Mr Gurney, and Thomas Martin, the

assistant engineer. Some of the small connecting rods were injured; the more important working parts of the carriage were either too hot to be handled, or too strong to be damaged by the means then in the power of the mob. Here was an end to our proceeding further that day. Mr Gurney was much disabled, and Mr Bailey, our principal engineer, had to be taken on to Bath in a post carriage in an insensible state, from the injury he had received."

It does not appear whether the journey to Bath was completed by the steam carriage, or whether it was taken back to London for repair.

For four months in the beginning of the year 1831 Sir Charles Dance worked with Gurney's drags a steam-carriage service on the road between Cheltenham and Gloucester. Three double journeys were made each day, in all 396 regular journeys, amounting to 3644 miles, during which were carried 2666 paying passengers, who paid a total of £202, 4s. 6d. The expense for coke was £78, but about one-third of this had been used on experimental runs. Local feeling, however, was strongly antagonistic to the innovation, and various obstacles were placed in the way of the project, heaps of stones were piled on the road, with the result that an axle broke. The engineers in making the necessary repair overhauled the engine generally, and found that beyond the crank bearings there was no perceptible wear.

GURNEY'S STEAM CARRIAGE, 1831.

During this period, according to Dance, the steam carriages occasioned no accident, hurt or injury to any person whatever, and the engines were never out of order,

and were as perfect at the end as they were at the beginning. Dance seems to have got his passengers mainly by cutting down the coach fares, and the project was just beginning to show a working profit when the Turnpike Trust secured a new Act of Parliament under which they were enabled to considerably increase the tolls upon steam carriages. The same thing was being done in other parts of the country so that the prospect of making steam coaches a commerical success was seriously affected. At anyrate, Gurney, who gave up the steam-carriage problem at about this time, alleged the excessive tolls imposed as his reason for so doing, and a few years later applied to Parliament for a grant of money to compensate him for his losses, which he said were due to parliamentary action in passing the various tolls. He made out a direct loss to himself of £36,000, and an indirect loss very much greater. The grant was not made, but the Committee of the House of Commons appointed to investigate the matter recommended a grant of £16,000. They were of "an unanimous opinion, that notwithstanding various attempts made by Mr Watt, Mr Trevithick and others, that there was no one to dispute the claim of Mr Goldsworthy Gurney to the merit of having been the first person to apply steam carriages successfully to common roads."

Gurney appears not only to have held a very high opinion as to the value of his carriage, but to have succeeded also in inducing other people to think with him. A one-fortieth share of his patents was sold for £1000, and a one-sixth share for £5000. The purchaser in this case was General Viney of Gloucester, whose name has already been mentioned in connection with the "charvolant" or kite carriage. Viney afterwards sold his interest to Sir Charles Dance. The right to work the carriages on the Western Road, London to Exeter and Plymouth, and Bristol to Exeter and Plymouth, was let to Mr Hanning at a royalty of sixpence a mile, and Gurney was to supply the carriages at £1000 each. Contracts were also entered into for the

roads from London to Manchester and Liverpool, London to Brighton, Southampton and Portland, and London to Birmingham and Holyhead.

In 1831 Gurney had entered into an agreement with a Mr Ward to sell the Scotch patents for £15,000, and Ward, it appears, was to re-sell to other parties for £32,000, but the agreement fell through, according to Gurney, because of the excessive tolls imposed by the Turnpike Trusts, but the fact that there was a serious accident with one of the carriages in Scotland suggests another explanation. It had been arranged that before the transaction was completed one of Gurney's coaches should be set to work in Scotland. This was done, and all went well for some time, when, according to the papers of the day, a boiler explosion, with serious results, occurred:—

"Mr Gurney's steam carriage was on Wednesday night blown to pieces by an explosion of the boiler. The catastrophe occurred in the square of the cavalry barracks, where the carriage was exhibiting. It had gone round the square several times, and stopped at one corner of it, where some people came out. Two boys, sons of Mr Maclure, of the Port Eglington Inn, at that time entered, and were about to be followed by two gentlemen, when the boiler burst with a tremendous explosion, and shattered the vehicle into numberless pieces. The two boys were very severely injured in the face and other parts of the body, and they now lie in very precarious circumstances. The cause of the explosion has not been accurately ascertained."

Although Gurney and his steam carriages were the subjects of a considerable amount of laudatory writing in the press of the period, and the words "Gurney" and "steam carriage" had become almost synonymous,[1] there were not wanting people to protest against this unfair treatment of the other steam-carriage projectors, and to ridicule the

[1] "Instead of *journeys*, people now
May go upon a *Gurney*,
With steam to do the horses' work."
TOM HOOD, *Conveyancing*.

claims made by Gurney and by others on his behalf. One writer in 1840, perhaps in a somewhat exasperated frame

SIR CHARLES DANCE'S STEAM CARRIAGE, 1833.

of mind, said that Mr Gurney had no more to do with the *invention* of steam carriages than he had with the building of St Paul's Cathedral. It is now generally conceded that

the designs of Gurney were not of so practicable a nature as those, for instance, of Hancock.

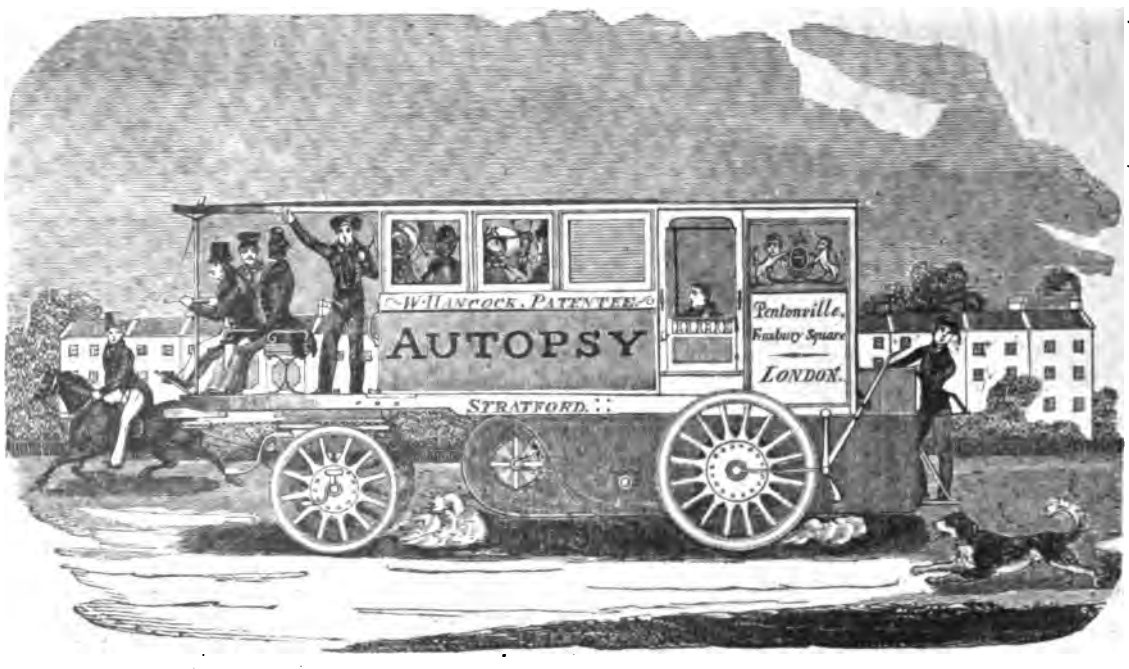
Gurney retired from the steam-carriage business in 1831. Sir Charles Dance, who had, as already stated, bought some of his carriages and used them for a steam-carriage service on the Gloucester and Cheltenham Road in 1831, kept on for a few years longer. In 1833 he had one of his carriages repaired, and fitted with a new boiler by Maudslay & Field of London. The new boiler, the joint invention of Dance and Field, was, like Gurney's, a water-tube boiler, and, in fact, it may be described as a duplication of Gurney's boiler. There were two sets of horse-shoe tubes alternating and crossing each other at an angle. The drag in its altered form with a coach attached is shown in the drawing. Several runs are recorded as having been made with successful results by this machine, and it attained speeds as high as sixteen miles per hour.

Maudslay & Field also made a new drag for Sir Charles Dance, which towards the end of 1833 made an experimental journey on the Holyhead Road, but the engines appear to have been too weak for the weight of the vehicle, which amounted to three and a quarter tons. After this we hear nothing further of Dance in connection with steam carriages.

Hancock's Steam Carriages

It is a little curious how Hancock[1] was led to direct his attention to the steam carriage. About 1824 he invented a steam engine in which the ordinary cylinder and piston were replaced by a flexible bag, which expanded and contracted as the steam was admitted and exhausted. This he found to answer fairly well on a small scale. The

[1] Walter Hancock was the son of a timber merchant and cabinetmaker at Marlborough, Wiltshire. He was born in 1799 and died in 1852. He served his apprenticeship to a watchmaker and jeweller in London, but about 1825 started as a mechanical engineer. His brother, Thomas Hancock, may be regarded as having been the founder of the indiarubber trade in England.



HANCOCK'S STEAM CARRIAGE "AUTOPSY" 1833. USED FOR THE CITY AND PADDINGTON OMNIBUS SERVICE.

subject of applying steam power to carriages was then in the air, and it occurred to him that his engine being light and simple would suit admirably for this purpose. When tried on a carriage, however, it did not come up to his expectations at all; but, having once started on the steam-carriage problem, Hancock continued to work at it, with engines of the ordinary construction, until about 1840; and it must be admitted that his designs were far more practical than most of the others evolved in his time. He gave his engines a fair chance of working successfully by according them a compartment to themselves; by arranging them vertically he removed the working parts as far as possible from the mud and dust of the road. To protect the passengers from the heat of the boiler he placed the engine compartment between the boiler, which was in the rear, and the passenger seating accommodation, which was in the fore part of the carriage. The boiler was of a quite special construction, and Hancock regarded it as his most important invention. It consisted of a number of flat rectangular chambers placed vertically side by side above a fire grate. The chambers were about two inches thick, and were in communication with each other at top and bottom; they were kept at a certain distance apart to form passages for the flame from the fire grate, by means of a series of round protuberances formed by bulging the metal of the sides outwards at regular intervals, those of one chamber bearing against those of the adjoining chambers. The protuberances also served to stiffen the sides. The average boiler pressure was 100 pounds per square inch. The draught was produced by a revolving fan. The engine was a double-cylinder vertical engine; its crank shaft was connected to the rear axle by chain gearing, and the chain wheel on the crank shaft was driven by means of a clutch in order that the engine might be worked when the car was stationary, for the purpose of keeping the fan and the boiler feed pump in action. The exhaust from the engine was discharged

under the fire grate of the boiler. The road wheels, which were of wood, were capable of a certain limited rotary motion in relation to the axle to allow the car to turn corners.

During his twelve or fourteen years' connection with motor-car movement, Hancock built nine or ten different vehicles; they were for the most part of the nature of omnibuses[1] and intended for public service in London. His carriage, "The Infant," which plied on the road between Stratford and London in 1831, was the first motor vehicle that ever carried paying passengers.

In August 1834 he commenced running two steam carriages between the City and Paddington *via* the Angel and Euston Road, and the papers of the period give a very good account of their working. There were plenty of passengers, the boilers generated abundance of steam, and every part of the machinery worked with complete success. *The Times* of September 3rd records a trifling accident to one of them. The "Autopsy," when nearing Paddington, came to a sudden stop without apparent cause, and in preference to repairing the machine on the road Hancock sent to his workshop for the "Era," with which he hauled the other home. The "Era" was provided with a two-speed gear, which was considered a novelty at that time, and the slow motion was brought into action in taking the "Autopsy" up Pentonville Hill. This car, which was built for eight inside and six outside passengers, was put on the road in place of the "Infant," which had been running with the "Autopsy."

The undertaking was given up at the end of November, when it was stated the two carriages had carried nearly 4000 passengers. The reason for the discontinuance is not clear; possibly the roads owing to wet weather became too difficult. In October a part of the route had been

[1] George Shillibeer, a coachmaker in Paris, came over to London in 1829 and started the first line of omnibuses, that from Paddington to the Bank along the Euston Road.

newly laid with four or five inches of macadam. This was before the days of steam rolling, and must have been a severe trial, but the "Era" worked through it successfully with the aid of its slow-motion gear, although one of the horse omnibuses stuck and could not be moved without the aid of an extra horse. We are not told how the "Autopsy" got along; possibly Hancock was too wise to try it, as it was known to be deficient in engine power and had not the advantage of the speed gear. The passengers in

THE "ENTERPRISE" STEAM OMNIBUS, BUILT BY WALTER HANCOCK IN 1833.

the carriage were exposed to a certain amount of vibration, but this seems to have been regarded with less disfavour than the smell from the oil in the cylinders.

In January 1835 the "Era," re-painted, and re-christened the "Erin," was taken over to Ireland and run in Dublin for a short time by the Hibernian Steam Coach Company. By the month of August, however, it had been returned to England, and we find it making a run to Marlborough and back. A log of this trip was published by one of the passengers, from which it appears that the journey of seventy-five miles took about twelve hours each way. Deducting for stoppages the average speed was 9·6 miles per hour on the outward journey and 9·8 on the homeward journey. The

only accident was the breakage of one of the bands of the blower. The car was not built for long journeys, so that it had to stop for about fifteen minutes every ten or twelve miles to take up water. The water was sometimes difficult to obtain and was frequently muddy; it had to be charged into the tanks by buckets. During these stops the fire dropped because the blower was not working, and it was only after a mile or two had been run that the carriage got up to its proper speed. The compiler of the log remarked that the steam carriage was everywhere well received, and that the bystanders were always ready with assistance when required. In the same year, 1835, the London and Birmingham Steam Coach Company made use of one of Hancock's carriages for some experimental trips. In May 1836 Hancock again started a line of coaches on the Paddington road with the "Erin" (formerly the "Era"), the "Enterprise," and the "Autopsy." His early carriage, the "Infant," built in 1826, which had done a good deal of work, was also repaired for use in cases of emergency. The work was done mainly by the "Erin" and the "Enterprise," as it was found that the engines of the "Autopsy" were too small. In July the "Automaton" was put on, and the undertaking was carried on until the middle of September, when about 4200 miles had been covered and 12,761 passengers carried. During this period the carriages had been run every day except Sundays, and this over a road which was held by competent authorities to have been a bad one. Ogle, another steam-carriage builder, in his evidence before the Parliamentary Committee on Turnpike Trusts, 1839, said that it was the most difficult road for locomotive carriages in England; no doubt this was a somewhat exaggerated view of the case; but it is borne out to some extent by an article in the *Morning Chronicle*, 19th August 1834, in which it is stated that "no roads in the neighbourhood of the Metropolis, and few in the kingdom, are more difficult to travel than that which Mr Hancock has chosen for the scene of his operations."

Hancock seems to have been a very modest and retiring man. A letter of his which appeared in 1831 sets forth his views in very temperate language:—

"Railways of course afford the speediest means of transit, but a few hours saved is not such an object with the majority of travellers as to induce them to forsake the pleasures of the common road. Steam carriages form the medium between railways and horse coaches, and had the coachmasters generally been a little more liberal and

HANCOCK'S STEAM CARRIAGE 'AUTOMATON," 1836. USED FOR THE CITY AND PADDINGTON OMNIBUS SERVICE.

unbiassed in their views, the public at large would have had demonstration of their effect long since. I have had no body of capitalists to thank for either cash or candid investigation, for want of which support the public are at this moment quite unaware of the perfection to which I have brought my carriages and the work which they have performed on the public roads; whilst I have been openly desiring inquiry, the railway engineers have been receiving

almost unbounded and blind support; how far a profitable return for which will be made remains to be proved.

"Some months since I offered Lord Lichfield to convey the mails at twenty miles an hour, and if my experience had not borne me out I should certainly never have made such an offer.

"It is true that many mere speculators have disgusted and prejudiced the public against common road steam-carriage conveyance by sending forth exaggerated accounts of performances which have been carried out only upon the drawing-board or writing-desk; by these the subject has been sadly overrated; no spare drags have been by them deemed necessary; but I am quite willing to admit, that if three drags up and three down should be required on the London and Birmingham road daily, that I would recommend the whole stock to consist of twelve drags; the railways for a like distance would have eighteen locomotives; this provision, in either case, is necessary to ensure sufficient time to clean, inspect or repair. . . .

"Of course I am in no small degree mortified, after having spent fourteen years of the prime of my life to perfect this invention, to meet with less of public encouragement than of clamour and prejudice, when I well know that society would be benefited by the general adoption of steam locomotion on common roads; but I have yet hope that at no far distant time it will be a favourite mode of transit; and I beg to observe that this hope is not founded on opposition to railways, but merely to afford the public a wholesome competition.

"Certainly, the railway engineers have no cause for complaint against the construction of common road locomotives, the former having copied rather copiously from the latter: I would instance their general arrangement of machinery, which is from Mr Gurney; the extended surface of boiler in equal space from myself, as well as the adoption of double valves to their pumps; again increasing

the draft by passing the waste steam up the funnel, from Mr Gurney, with several others; and it may be fairly asserted, that until they copy more from common road locomotives in many other material points they will not remove the evils at present so justly complained of."

The estimate prepared by Hancock at the beginning of 1839 of the expenses of a steam-carriage service between London and Birmingham is of particular value as a summary of his views of the cost and efficiency of steam carriages after fourteen years' experience.

He proposed to have one passenger service each way per day, to be performed at a speed of from twelve to fourteen miles per hour by a drag with a train of three coaches, carrying altogether eighty passengers at ten shillings per head, and one and a half tons of goods at a half-penny per pound. The daily earnings would thus be £94, but an allowance of twenty per cent. was made for light loads. The working expenses he estimated at £48 a day, including coke, oil, guards, stokers, tolls, repairs and renewals, rent of stations, pay of attendants and contingencies. There was also to be a goods service of four drags, each with a van attached, to make the journey to and fro in a day at a speed of ten miles an hour and carrying thirty-two tons.

To work these services there were to be four passenger drags at £1600 each, nine common carriages at £130, eight goods drags at £1600, and seven vans at £80. The charging stations were to be placed not more than ten miles apart.

Hancock's connection with the steam-carriage movement seems to have terminated in 1840. He was in that year occupied in building a new railway locomotive, which was tried on the Great Eastern Railway, and seems to have been arranged on the same lines as his steam carriages. Later on he joined his brother in the indiarubber business.

The highly ornate coach shown in the illustration was built by Dr Church of Birmingham about 1833; it was

intended to carry fifty passengers. As will be seen, a single front wheel was used, and the driving wheels

CHURCH'S STEAM COACH, 1833.

were spring wheels eight feet six inches in diameter. They were mounted on separate axles, each geared to the engine crank shaft by chains. The boiler consisted of

a series of double tubes arranged vertically around a central firebox, and communicating with it, and the draught was produced by a fan worked by the engine. The coach was built for the London and Birmingham Steam Carriage Company, but beyond a few trial runs it seems not to have done any work, although Church appears to have persevered with the subject until 1838.

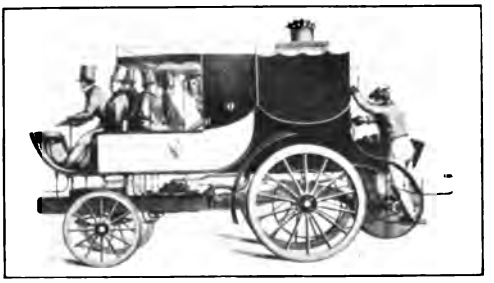
Another steam carriage was being built in Birmingham at the same time as that of Church; it was the invention of W. G. & R. Heaton. It attained a speed of seven or eight miles an hour, and the Heatons then undertook to construct for a Birmingham company a carriage which was to maintain an average speed of ten miles an hour. The carriage was built, but it was found impossible to attain the prescribed speed and the Heatons then gave up the matter.

CHURCH'S STEAM COACH, 1833 (SIDE VIEW).

The carriages built by Summers & Ogle in 1831 were the most speedy vehicles of the period. Their first carriage is said to have attained a speed of thirty-two to thirty-five miles an hour, with a large number of passengers on board. It was a three-wheeled vehicle, and had a multitubular boiler mounted on the frame behind, and separate from the carriage body, and a two-cylinder engine. The second carriage, in which a three-cylinder engine was employed, travelled at the rate of fifteen miles an hour, with nineteen passengers; it made a journey from Southampton to Liverpool in 1832, with great success, as appears from the following account:

"STEAM COACHES.—From Liverpool we learn that the steam coach of Messrs Ogle & Summers, which has

lately been making a trip to Birmingham, entered the former town on Monday, amidst the acclamations of a crowded populace. Among the party brought by her were the Messrs Brotherton, the late extensive coach proprietors between that place and Manchester. Thus has been accomplished by steam power, on our common roads, a journey from Southampton, through Oxford and Birmingham, to Liverpool, over as irregular a surface of country as perhaps could have been selected for the purpose of the experiment. The objects sought, and of which there is a proof of accomplishment by these gentlemen, are, in the first place, a safe method of generating steam in convenient space, in sufficient quantity to enable them at all times to propel vehicles on common roads at any desired speed, and with such command of power as will overcome increased resistance from occasional obstacles, fresh gravelled, soft or hilly roads. Secondly, the safe application of this power to vehicles of such construction as will ensure action and progress on any description of ground, and, nevertheless, be under the immediate control and certain guidance of the conductor."—*The Ladies Magazine*, November 1832.



MACERONI AND SQUIRE'S STEAM CARRIAGE, 1833.

The carriage built by Maceroni & Squire in 1833 was one of the most simple and compact to be seen at that time. It had a multitubular boiler, the joint invention of the builders, provided with a fan draught and placed behind the carriage, and a horizontal two-cylinder engine below the body of the carriage. At a trial run from

Paddington to Edgware in October 1833, with ten persons on board, the average speed was ten miles an hour; and on another occasion it ascended Harrow Hill at the rate of seven miles an hour. This carriage plied daily for some weeks between Paddington and Edgware in 1833, and again in 1834 between Oxford Street and Edgware. Maceroni was not a man to hide his light under a bushel, and accordingly we find numerous accounts of the doings of his carriages in the newspapers of the time, and he himself wrote several pamphlets on the subject of steam locomotion. The success attained, however, does not appear to have been great, and in 1834 Maceroni & Squire dissolved partnership after having built two carriages, which remained in the possession of Maceroni and were soon afterwards taken abroad, one to Paris and the other to Brussels. They attracted considerable attention in both places, and in Paris the performances of Maceroni's carriage was very favourably compared with that of Dietz. Asada, the man who took the carriages abroad, is stated to have sold the French patent rights for a considerable sum, which he retained himself, and Maceroni failed to recover any of it from him. Maceroni made several other attempts to embark upon the building of steam carriages, and as late as 1841 one of his carriages was built by an engineer at Greenwich for the General Steam Carriage Company, but some hitch arose as to payment, and the carriage remained in the hands of the builder.

In 1833, Richard Roberts, of the firm of Sharp, Roberts & Co., Manchester, made a steam carriage, of the construction of which very little is known beyond that it embodied the now well-known compensating gear for allowing one of the driving wheels to travel faster than the other. The mechanism itself was already known in connection with other applications; it is, for instance, described in connection with a dynamometer in White's *Century of Inventions*, 1822.

The Steam Carriage Company of Scotland, in 1834,

established a line of steam coaches between Glasgow and Paisley. They were built at Edinburgh, from the designs of John Scott Russell, well known in connection with the steamship *The Great Eastern.* They had multitubular boilers and vertical two-cylinder engines, the crank shafts of which drove the rear axles by spur wheels. The coaches ran regularly for many months, and had become very popular, when one of them, through overturning upon a heap of stones, threw its weight upon the boiler which burst and killed a number of the passengers. The use of the carriages on the road was then interdicted by the Court of Session. Two of them were subsequently to be seen in the neighbourhood of London.

HILL'S STEAM COACH, 1840.

About the year 1840, F. Hill, of Deptford, brought out a steam carriage which, like that of Roberts, was fitted with a compensating gear. It made some very successful runs, including a trip from Camberwell to Brighton and back in one day. The account of this trip brings out very clearly one of the great difficulties of the steam carriage. One-fourth of the time taken on the journey was occupied in charging the water tanks. The coach shown in the illustration appears to have been intended for a service between London and Birmingham.

In addition to the carriages enumerated in the foregoing account a great many others which do not require any special mention here were built in the period under discussion; in many cases, indeed, nothing is known

beyond the fact that the carriages were made or projected.

It is not a little remarkable that attention was directed solely to passenger carriages. It appears to have been the general opinion that the carriage of goods at low speeds was quite out of the question.

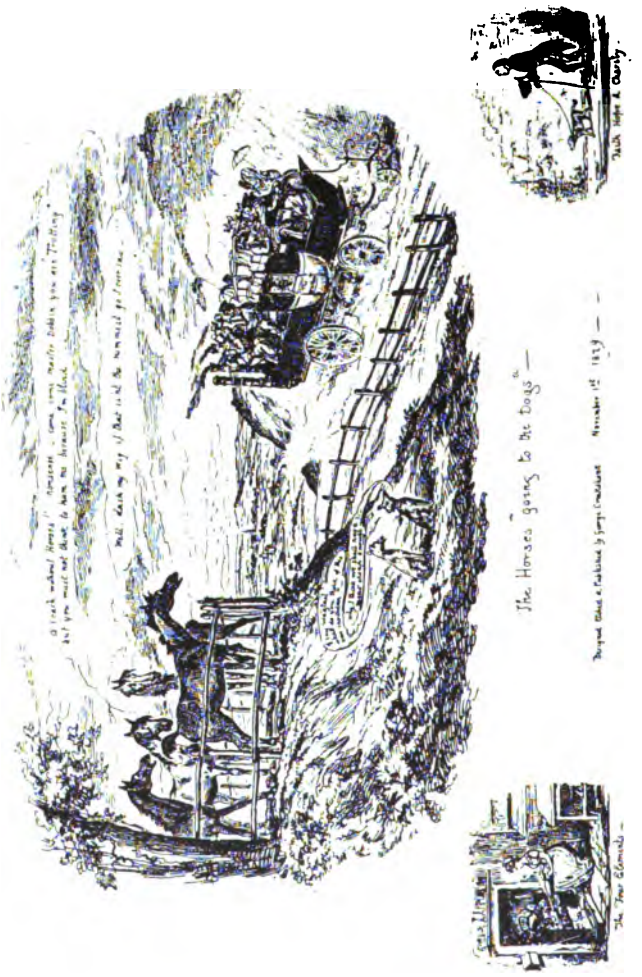
The activity in this period was due to a growing knowledge of the capabilities of the steam engine, to the

HANCOCK'S "AUTOPSY," "ERA" AND "INFANT."

urgent need of improved means of internal communication, and to the improvements effected in the condition of the main roads by Macadam, Telford and M'Neil, then for the first time rendering possible with any degree of success the use of mechanical power thereon.

But what with the difficulties as to tolls, the imperfections of the roads, and, indeed, of the engines themselves, by 1840 all this interest appears to have died out. This point of the imperfections of the engines themselves is frequently overlooked. However ingenious and skilful the design of some of the carriages may have been, the material, workmanship and skill now available was then altogether wanting. One of the enthusiasts of this period —J. H. Clive—came to the conclusion that "it is impossible

to build an engine sufficiently strong to run even without a load, on a common road, year by year, at the rate of



fifteen to twenty miles an hour. It would break down. Cold iron, at that speed, cannot stand the shock of the momentum of a constant fall from stones and ruts of even

an inch high." George Stephenson, too, held that "steam carriages on ordinary roads would never be effective, or, at least, sufficiently serviceable to supersede horse carriages"; one must make allowance here, of course, for a natural bias in favour of railways.

Another consideration that presents itself is that nearly all the steam-carriage builders of the period devoted their attention mainly in the direction of stage coaches, and that railways were at about the same time entering the field, the Liverpool and Manchester line having been commenced in 1826. In 1829, at the Rainhill competition, there appeared locomotives by Burstall, better known in connection with steam road carriages, Braithwaite and Ericsson, Hackworth, and Stephenson. Blenkinsop's engine had come out in 1812, and Hedley's "Puffing Billy" at about the same date.

In view, then, of the competition of this powerful rival, of the difficulties inherent to the problem itself, and of the great opposition in the form of tolls and otherwise that had to be encountered, it is not surprising that by 1840 the problem of carrying passengers by steam power on common roads had been abandoned. It was not again taken up in this country for nearly twenty years, during which period the farm engine and the traction engine began to engage attention.

The movement in England was reflected to some extent in France, where Pecquer is said to have made a carriage fitted with the compensating gear in 1828; he was followed by Dietz, who built an eight-wheeled drag about 1834, Galy-Gazalet, Hamond, Leroy, and others.

CHAPTER VII

THE APPLICATION OF COMPRESSED AIR

It is well known that the power of a steam engine or other prime mover may be expended in compressing air, which may be transmitted through pipes to any required point, and there caused to do work in expanding against the piston of an engine precisely similar in construction to a steam engine. This system is extensively used for working machinery in mines, and to some extent in workshops and factories, particularly in America.

Instead of forcing the air through a system of pipes, it may be compressed into portable reservoirs adapted to be carried in a vehicle, and thus be made available for working an engine for propelling the same, as is actually done in the case of tramcars on various lines in France. This system is one of storage of energy, comparable with the use of electrical accumulators, as opposed to the use of prime movers, such as the steam or the petrol engine. Such a system has many advantages, the energy is stored in a convenient form for application, and there is no smell, heat or smoke, and comparatively little noise. In the case of compressed air there is obtained an immense range of power and speed, which obviates the necessity of a variable-speed gear, and the utmost facility in starting and stopping the engine and car.

On the other hand a storage system is necessarily less flexible than one employing prime movers, a certain radius of action round the charging stations is alone possible. This radius is limited by the weight of the storage medium

employed. In the case of compressed air it does not appear possible, having due regard for safety, to reduce the weight of the reservoirs below about ten times that of the original charge of air. The air is, of course, carried at very high pressures, 1000 pounds per square inch and over, in order to bring the bulk of the reservoirs within convenient dimensions; but the pressure has no important bearing upon the weight of reservoirs required to carry a given weight of air. Increased pressure, while enabling smaller reservoirs to be employed, necessitates their being of greater thickness in the same proportion.

The consumption of air, even in a well-designed and constructed road carriage, would probably amount to five pounds per ton of gross load. For a ten-mile journey, allowing for a residuum of air which cannot be utilised, the initial charge would have to be perhaps sixty-four pounds; this with ten times that weight for reservoirs brings the total to 704 pounds per ton gross, so that approximately one-third of the total load would be taken up by the reservoirs and the air.[1]

Still, for urban traffic, such as omnibuses, parcel delivery vans, etc., in which an extended radius of action is not looked for, the advantages attending the use of compressed air may be regarded as sufficient to counterbalance this drawback. Unfortunately, however, for experimental work in this direction, in order to show a financial success it is necessary to secure a fair degree of efficiency in the entire system, that is to say of power at the rims of the road wheels in proportion to the coal used in compressing the air, and this can be done only when compressing plant on a large scale is employed.

The idea of applying compressed air for the propulsion of road vehicles is a fairly obvious one, but it is not gener-

[1] A paper read by the author before the Liverpool Branch of the Self Propelled Traffic Association in 1897, and printed in *The Automotor Journal*, vol. i., p. 213, contains an investigation of the problem of applying compressed air to road vehicles based mainly on the results obtained on the Paris tramways.

ally known that it dates back to the very beginning of last century, when George Medhurst, of London, projected a general system of transport on common roads by the aid of motors driven by air, which was to be compressed at convenient stations by windmills, watermills, or by hand. Medhurst endeavoured to form a company with a capital of £50,000 to work this project, but the scheme appears to have come to nothing, although Luke Hebert, in his *Encyclopædia*, states that he had heard that Medhurst had applied his invention in practice. His patent specifications are very interesting documents; that of 1799 relates to "a condensing wind engine capable of being applied to all kinds of purposes in which steam, water, wind, or horses are employed." That of 1800 to "a new improved method of driving carriages of all kinds without the use of horses by means of an improved Æolian engine, and which engine may also be applied to various other useful purposes."

Medhurst's ideas were so far in advance of his time that it is worth while to quote here a portion of his second specification, No. 2431, A.D. 1800, which does not appear to have received the attention to which it is entitled:—

"The power applied to the machinery is compressed air, and the power to compress the air I obtain generally by wind, assisted and improved by machinery described in this specification; and in order to render my invention universally useful, I propose to adapt my machinery and magazine so that it may be charged by hand, by a fall of water, by a partial vacuum obtained by wind, and also by explosive and effervescent substances, for the rapid conveyance of passengers, mails, despatches, artillery, military stores, etc., and to establish regular stage coaches and waggons throughout the kingdom to convey goods and passengers, for public accommodation, by erecting windmills, watermills, etc., at proper intervals upon the roads, to be employed in charging large magazines at these stations with compressed air, or in raising large reservoirs of water by wind, etc., by the power of which smaller portable

magazines may be charged, when required, by machinery for that purpose."

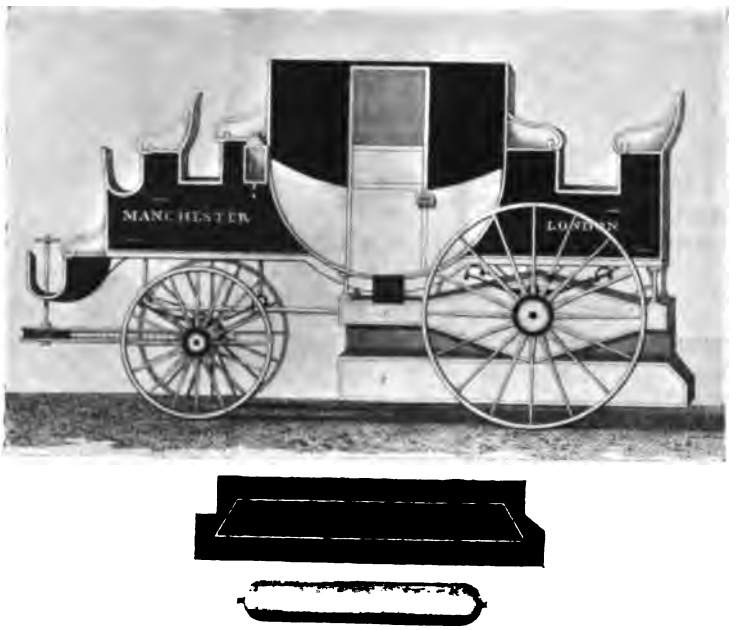
Small carriages were to be worked by rotary engines, larger carriages by reciprocating engines provided with a special gear for varying the power. Another project of this inventor was the propulsion of carriages by a gunpowder engine; this is described in connection with an artillery waggon.

Medhurst was the inventor of the pneumatic despatch system, and published several pamphlets relating to his inventions.

William Murdock, the celebrated assistant of James Watt, took up the problem of transmitting power by compressed air, and is stated to have made in 1819, in conjunction with David Gordon, like himself also a steam-carriage projector, some experiments in connection with compressed-air carriages, but nothing is known as to the results obtained.

Between 1827 and 1832 several projects for compressed-air carriages made their appearance. The first was that of William Mann, of Brixton. He turned his attention to the matter in 1827, obtained a patent in 1829, and published a pamphlet on the subject in 1830. Mann advocated compression in stages, now recognised as essential for the production of highly-compressed air, and the erection of power stations along the high roads at intervals of from fifteen to twenty miles, or, in place of such stations, a continuous iron main, with power stations in the colliery districts. The accompanying illustration of Mann's proposed carriage is reproduced from a lithograph in his pamphlet. The air was to be stored in fifteen reservoirs having a capacity of seventy-five cubic feet in the aggregate. This supply the inventor deemed sufficient for a run of fourteen miles with air at thirty-two atmospheres pressure; with air at sixty-four atmospheres he held that thirty-four miles could be covered, and at an average cost of about a penny per mile. At this period a good deal

was being done in the way of supplying coal gas for lighting purposes in portable reservoirs, just as oxygen and other gases are now sold, and Mann and other inventors make frequent reference to the pumps and reservoirs employed in this industry. It appears that the reservoirs in use by



1. Case containing piston and cylinder working on the axle of the hind wheels
2. Case containing reservoirs of compressed air.
3. Fifteen reservoirs containing seventy-five cubic feet.
4. A reservoir taken out of the case.

"This carriage is constructed to carry seventy-five cubic feet of compressed air, which, at a density of thirty-two atmospheres, is sufficient to propel it fourteen miles ; at forty-eight atmospheres, twenty-three miles ; and at sixty-four atmospheres, thirty-four miles. The average cost of the power will be about a penny per mile."

MANN'S COMPRESSED-AIR CARRIAGE, 1830.

the Portable Gas Company for supplying gas at thirty atmospheres pressure had a capacity of three and a half

cubic feet; their diameter was twelve inches, and they were made of iron one-ninth of an inch thick.

In his pamphlet, which is entitled, *A Description of a New Method of Propelling Locomotive Machines, and of Communicating Power and Motion to all other kinds of Machinery*, Mann discusses the question of the pneumatic distribution of power generally, and advocates a public supply of compressed air, by means of mains in the streets, such as has now been carried out in Paris by Messrs Popp & Conti. He instances the case of the city of Birmingham, the artizans of which "may be supplied with cheap power by means of compressed air, just as they are now supplied with cheap light by means of gas." It is interesting to note that Birmingham was, a good many years afterwards, the scene of an attempt at such a scheme. Mann was of opinion too, that it would be a good plan to make persons confined in Clerkenwell and other prisons earn their dinners by employing them to compress air for propelling His Majesty's mails throughout the kingdom.

Bompass, another inventor of this period, considered that the most suitable pressure for storing the air was about 100 atmospheres. He pointed out that the weight of the reservoirs is nearly the same, whatever be the pressure adopted.

Lemuel Wellman Wright, a prolific inventor in many different directions, was the author of a project for compressed-air carriages, which is specially interesting as containing the first suggestion of what is now recognised as the root idea in the economical use of compressed air as a motive power, *i.e.*, heating it or injecting steam into it prior to its entry into the working cylinder. Wright also proposed to utilise and check the momentum of the car when going down hill, by applying it to actuate a pump for compressing air into the reservoirs.

There is no distinct evidence that any of these inventors carried their ideas into practice. Some reason, however, exists for thinking that one Fordham did make

a compressed-air carriage about 1832, but particulars relating thereto are wanting. Fordham estimated that coaches could be worked by compressed air at fourpence or sixpence a mile, as against two shillings for horse traction.

The first instance of the actual application of compressed air to purposes of locomotion, of which we have any authentic account, is that made in France about the year 1840 by Andraud and Tessié du Motay, but, although these inventors had in view also the application to road carriages, the only vehicle actually constructed was one for running upon rails. It was adapted to carry eight passengers, and the working pressure in the cylinder was three atmospheres; the air was stored at seventeen atmospheres pressure, but the inventors contemplated pressures as high as sixty atmospheres, to be attained by compression in stages, as well as the heating of the air before its admission to the cylinder. They were the first to indicate the necessity of a reserve supply of compressed air for use in hill-climbing or for other contingencies when the pressure in the main reservoirs had fallen towards its lower limit.

Fifteen years later another compressed-air carriage was seen upon the streets of Paris. It was the invention of a man named Julienne. It weighed about a ton when loaded, and carried its supply of air at a pressure of twenty-five atmospheres.

But before this date a compressed-air carriage had been tried on the road in England. It was the invention of Anthony Bernhard, Baron von Rathen, and was run from Putney to Wandsworth on several occasions in 1848. The carriage weighed three tons, and on its first run, with the reservoirs only partly charged with air, it covered a mile at the uniform rate of eight miles an hour. On another occasion it carried about twenty passengers from Putney to Wandsworth at a speed of over twelve miles an hour. The reservoirs were in the form of tubes, and were of seventy-five cubic feet capacity; the air was stored in them at a

pressure of from fifty to sixty atmospheres. The working pressure in the engine cylinders was five atmospheres, and a reducing valve was employed to bring down the storage pressure to the working pressure. Von Rathen's system comprised special methods of cooling the air during compression and of supplying heat to it when working. The ultimate fate of this carriage is not known, but the inventor was engaged in inventing compressed-air engines twenty years after this date.

The only really valuable work in reference to the application of compressed air to vehicles has been done in connection with street tramways, and again in France, by M. Mékarski. The attempts of Scott-Moncrieff, of Beaumont, and more recently of Hughes and Lancaster, in this country may be passed over as having remained more or less in the experimental stage, whereas the Mékarski system has been at work on the tramways of Nantes for upwards of twenty years, and is now at work in Berne and upon several lines in the neighbourhood of Paris. In a few words, the essential features of the Mékarski system are: (1) high pressures in the storage vessels on the cars (starting with thirty atmospheres at Nantes, this pressure has been increased in each succeeding installation, first to forty-five, then to sixty, and finally to eighty atmospheres, say 1200 pounds per square inch, on the Versailles line). (2) The air, on its way from the storage vessels to the cylinders, passes up through a vertical cylinder containing hot water, and thus becomes heated and charged with vapour. (3) It also passes through an automatic reducing valve whereby it is reduced to a constant and comparatively low working pressure. The engines are arranged to work directly on to the car axles. There seems to be no question that the Mékarski system as applied to tramways is a success both mechanically and financially.

Another system in use on French tramways is that of Messrs Popp and Conti, already mentioned in connection with the Paris compressed-air supply. These constructors prefer to use lower storage pressures, say from fifteen to

twenty atmospheres, and are therefore compelled to charge more frequently. Their engine is compound and geared to the car axle, and they heat the air before using it, and on its passage from the high-pressure to the low-pressure cylinders, by means of a small coke stove.

The success of the petrol car has naturally led to a renewal of the attempts to solve the problem of propelling road vehicles by means of compressed air. So far no practical result has been arrived at, but Messrs Molas, Lamielle & Tessier in 1899 constructed a parcel's delivery van, worked by compressed air, of which a full description has been published.[1] These constructors stored compressed air at a pressure of about 290 atmospheres (over 4000 pounds per square inch) in reservoirs which weighed less than five times that of the charge of air, but it is not stated to what stress the metal was subjected, and one cannot but think it must have been higher than a proper regard for safety would suggest. At a short trial run held in Paris a course of five miles was traversed with an expenditure of 105 pounds of air, and the gross load is stated to have been four and a half tons; this gives a consumption of air of somewhat under five pounds per ton-mile.

At the Paris Exhibition of 1900 another car by these makers was exhibited, as well as two or three by other constructors.

[1] *The Automotor Journal*, vol. iv., pp. 238, 255

CHAPTER VIII

STEAM CARRIAGES, 1858-1881

It has been seen in a preceding chapter how the steam-carriage movement of the thirties of last century was impeded by the excessive tolls imposed, and that in fact these tolls were the ostensible reason for Gurney's retirement from the steam carriage field. The tolls were imposed by local road authorities in virtue of powers given them by private Acts of Parliament, and they varied considerably in different parts of the country. The road authorities were composed mainly of landowners and others interested in agriculture, and their action in procuring these powers was, no doubt, to some extent at anyrate, a purely selfish one; they feared that the spread of the steam carriage would reduce the number of horses required, and thus the consumption of oats and other provender. It must be understood that the question in these days was merely one of tolls; there were no restrictions whatever upon speed or upon the structure and proportions of the vehicles. In spite of a good deal of agitation, no steps were taken at that time to reduce or render uniform the tolls, but with the increasing use of the traction engine, pressure was again brought to bear upon the Government, and in 1861 a Bill was passed in Parliament which imposed a uniform scale of tolls in all parts of the country.[1] The Government action, however, cut both ways, for the new Act contained clauses regulating the size and weight of the engines and the maximum weight upon each pair of

[1] 24 & 25 Vict., c. 70.

wheels, and it prescribed the maximum speed of ten miles an hour in the country and five in towns and villages. Further, at least two persons were required to be in charge of each locomotive. By an amending Act, passed in 1865,[1] the maximum speeds were reduced to four miles per hour in the country and two miles in towns, and an additional attendant was required to walk, carrying a red flag, at least sixty yards in advance of the engine, and to warn riders and drivers of horses of its approach.

The original Act cannot be said to have seriously affected the prospects of the steam carriage; ten miles per hour was reckoned a good speed at that time; it was the speed for which Rickett built his steam carriages, or rather passenger locomotives, in 1858 to 1861. The amending Act of 1865, however, constituted a deathblow; enthusiasts continued to build carriages and managed to run them from time to time in evasion of the law, but any commercial application was out of the question.

Another amending Act,[2] passed in 1878, did not in any way improve the position of the motor car, in spite of the fact that a Parliamentary Committee[3] a few years before had reported strongly in favour of the removal of all restrictions upon such vehicles; that is to say, they recommended that all self-contained vehicles weighing under six tons should be placed on exactly the same footing as horse-drawn vehicles. This is precisely what automobilists are still asking for.

From the period of the steam-carriage boom down to late years, almost the only man who made motor cars in England, on a commercial footing, was Rickett of Buckingham, who, about the year 1860, built a number of steam carriages. As will be seen from the illustration, they did not justly deserve the name of carriages; they were more like small traction engines in appearance, and the seating

[1] 28 & 29 Vict., c. 83. [2] 41 & 42 Vict., c. 77.
[3] Report from the Select Committee on Locomotive Engines on Roads, 1873.

accommodation was made quite subordinate to the boiler. They were built with a seat in front for three passengers, and the stoker stood behind. An average speed of ten miles an hour was attained, and by the use of a speed gear hills of one in ten could be climbed. The boiler pressure was 150 pounds to the square inch, and a two-cylinder engine was used. The carriage weighed, empty, thirty hundredweights, and it carried twelve hundredweights of water,

RICKETT'S STEAM CARRIAGE, 1861.

sufficient for a run of ten miles, and three hundredweights of coal.

In one of these carriages the Earl of Caithness travelled 150 miles in two days in a very mountainous district, from Inverness to Barogell Castle. In his earliest carriages Rickett used chain gearing to transmit the power of the engine to the road wheels; he gave this up for spur gearing, and, finally, he built a carriage in which the driving wheels were driven direct by the engine connecting rod just as in an outside cylinder locomotive. This last engine weighed six tons and was used as a drag for hauling coaches.

In 1858 a Manchester firm of engineers, Daniel Adamson & Co., built for a Mr Schmidt a road locomotive intended for hauling an omnibus; it ran on three wheels and at a speed of eight miles an hour. It answered expectations fairly well, and in 1867 there is mention of a race between this engine and one made by J. W. Boulton of Ashton-under-Lyne. Boulton appears to have made several passenger road engines before that date. This particular machine ran a distance of ninety miles in one

CARRETT'S STEAM CARRIAGE, 1861.

day, carrying six persons, and over some parts of the run eight or ten, without stoppages except for water.

In 1861 W. O. Carrett of the firm of Carrett, Marshall & Co., Leeds, made the steam carriage shown in the illustration. It was shown at the Exhibition of 1862, and some years afterwards came into the hands of a gentleman in London who ran it about 800 miles, chiefly in Kent, and at night, so that it became known as the "Fly-by-night." After having been summoned several times for breaches of the Locomotives Acts he altered it to resemble a fire engine, and dressed the passengers up as firemen with brass

helmets, and in this way escaped interference from the police for some months, but in the end the machine was converted into a slow-moving engine. This carriage was mounted on three wheels, had a boiler of the locomotive type, adapted to stand 175 pounds per square inch pressure, and a horizontal two-cylinder engine geared to the rear axle, which was fitted with compensating gear. Its weight was about six tons.

Another steam carriage exhibited at the 1862 Exhibition was that of Yarrow & Hilditch; it had a vertical multitubular boiler, and each of the rear wheels was driven directly by a steam engine, the connecting rod of which engaged a crank pin on the outer side of the wheel. It was adapted to seat thirteen persons and weighed two and a half tons.

The feature of engines directly connected to the road wheels was present in the carriage built by Tangyes of Birmingham in 1862, which, like the foregoing, had a vertical multitubular boiler. The carriage built by A. Patterson in 1862 had the boiler and engines mounted on the front pair of wheels, which served both for steering and driving.

A small steam carriage constructed by Mr J. H. Knight in 1868-1870 has been described by him in *The Automotor Journal*.[1] It was originally fitted with a single-cylinder engine, geared by a chain to one of the rear road wheels, and with a vertical multitubular boiler. Not being found satisfactory in this state, a two-cylinder engine and a Field boiler were substituted. Three passengers could be seated in front, and the stoker stood on a firing platform behind. The weight of the car empty was about thirty-two hundredweights. Water for about six or seven miles was carried in a tank under the engine, and coal for about eighteen miles in a bunker at the back. On fair roads a speed of eight miles an hour was maintained. The carriage was after a few years converted into a small traction engine.

The steam wagonette of Catley & Ayres of York,

[1] *The Automotor Journal*, April 1897.

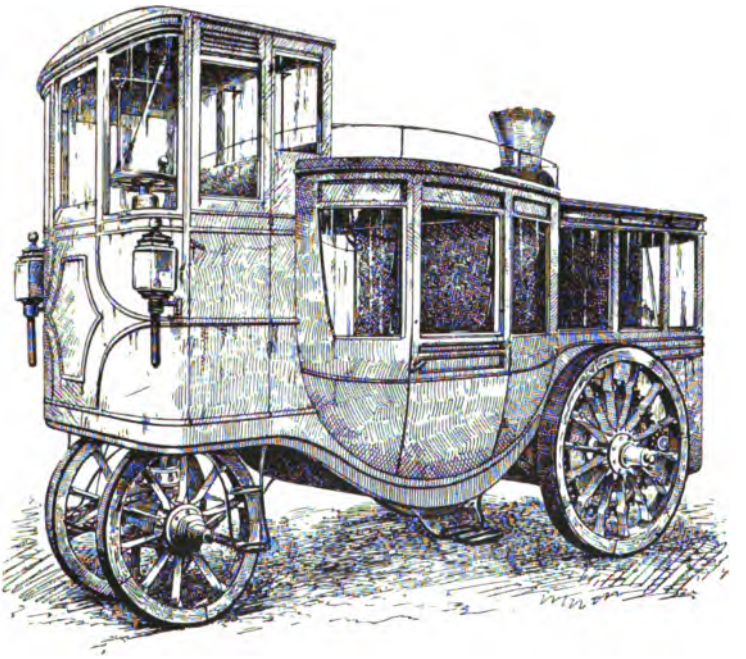
built in 1869, seems to have met with a fair measure of success. It made many journeys of eight or ten miles round York, carrying four persons, and a speed of twenty miles per hour was attained on good level roads. It was a three-wheeled vehicle driven by a two-cylinder engine, which was geared to the rear axle by spur wheels, and had a vertical boiler with a steam superheater in the smoke box. Its weight empty was fifteen hundredweights.

About the year 1870 several engineers in Scotland took up the construction of steam carriages and high-speed traction engines. In 1865 or 1866 A. W. Forbes of Edinburgh had made a small steam drag with a boiler of the locomotive type and a two-cylinder horizontal engine, but this does not seem to have remained in use, and the movement appears to have been started by R. W. Thomson, the original inventor, in 1846, of the pneumatic tyre. In 1867 Thomson invented what he termed a "road steamer," the wheels of which were fitted with thick solid indiarubber tyres. A large demand for these engines sprang up. They were really traction engines, but some of them were geared to run at high speeds, for hauling omnibuses, etc., and were sent to India and other places abroad for passenger services. They were built in Leith, in Lincoln, and at Ipswich and Thetford.[1]

Between 1869 and 1872 L. J. Todd of Leith constructed several steam vehicles. A small carriage which he made in 1870 was mounted on three wheels, and each of the two rear wheels was driven independently by means of a gut belt from a vertical engine. The engines were mounted on opposite sides of a vertical boiler. In 1872 he made a high-speed road locomotive for hauling mails and passenger coaches, and a steam omnibus for running between Edinburgh and Leith. Todd, it may be remarked, believed in rigid wheels rather than in the elastic tyres of Thomson. Another Leith man, Nairn, made in 1870 a steam omnibus

[1] *See* Fletcher, *Steam on Common Roads*, for a very full account of Thomson's road steamers and of the subject generally.

which was used in Edinburgh for some months. It weighed seven tons, carried fifty passengers, and could attain a speed of sixteen miles per hour on the level. In 1871 another steam omnibus of his construction ran regularly from Edinburgh to Portobello for some months. This had a three-cylinder engine, and when fully loaded with fifty passengers it weighed



RANDOLPH'S STEAM CARRIAGE, 1872. (Reproduced from *The Engineer*.)

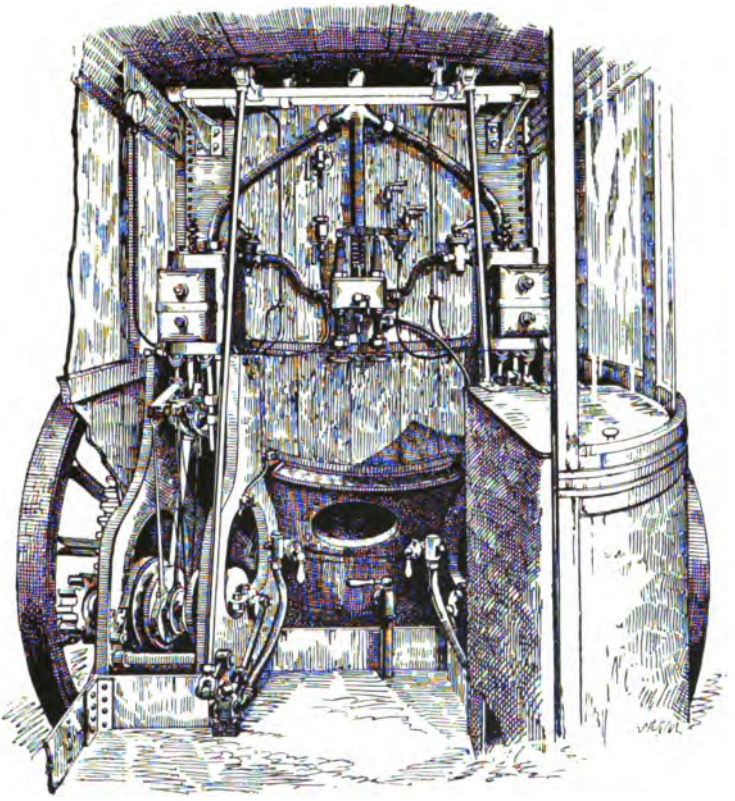
ten tons. Nairn seems to have used an elastic tyre built up of hemp rope.

A highly interesting carriage was built in 1872 for Charles Randolph, who, after retiring from the celebrated Glasgow engineering firm of Randolph & Elder, had devoted some thought to the application of steam power to road vehicles. This carriage was finished towards the end of 1872, and in the beginning of 1873 Randolph began

running it about the streets of Glasgow. He found no difficulty whatever in threading his way through the most crowded parts of the city, and in the busiest time of the day, and that without causing any trouble or annoyance to himself or to the public; on one occasion only did he notice a horse to be frightened. The vehicle was fifteen feet long, it could be stopped in its own length, and turned in a street forty feet wide; its speed on the level was six miles an hour; the engines were not of sufficient power in proportion to the weight of the vehicle to give the speed originally in view, eight to ten miles an hour. The weight when loaded with water and coal for a run of three or four hours' duration was four and a half tons. The closed body of the carriage was capable of seating six persons, and the driver's box in front two more, in addition to the driver. This box stood above the body of the carriage; it was completely closed in and provided with windows. The engine and boiler were in a compartment at the rear, in which was fitted a seat for the stoker. Each of the rear wheels was driven independently by a two-cylinder vertical engine, the transmission being effected by spur wheels. The exhaust was discharged into a silencer, in the boiler chimney, from which it emerged in an annular stream around the pipe, from which the gases from the fire grate escaped, and thus served to produce a draught. There was no visible steam or smoke. The engine was supplied with steam at a pressure of ninety to 120 pounds per square inch from a vertical boiler fired with coal. In front the vehicle was mounted on elliptical springs; behind, on an arrangement of spiral springs. The road wheels were ordinary carriage wheels, with tyres four and a half inches wide.

Although it worked so successfully, and the authorities shut their eyes to the breach of the law which occurred every time it was used, Randolph seems to have found his carriage somewhat of a white elephant. He himself

stated[1] that he had used the carriage *occasionally*, and expressed the opinion that such conveyances would not come into use as private carriages, although they might be found useful as omnibuses. Later on, several attempts



ENGINE AND BOILER COMPARTMENT, RANDOLPH'S STEAM CARRIAGE.
(Reproduced from *The Engineer*.)

were made to sell the carriage, and finally it was presented to the South Kensington Museum, where it is now preserved.

The three-wheeled carriage which Loftus Perkins made

[1] In his evidence, given May 23, 1873, before the Parliamentary Committee on Locomotive Engines on Roads, upon which this account is based.

in 1871 was, as Mr Fletcher[1] has pointed out, very much on the lines of the carriage made by Cugnot a hundred years before; it had the engine and boiler mounted above the front wheel, which was at the same time both a driving and a steering wheel. The engine was a high-speed compound engine, supplied with steam from a Perkins' water-tube boiler. The steam pressure was as high as 600 pounds per square inch.

The steam brougham which H. A. O. Mackenzie of Diss, Norfolk, built in 1874, was a remarkably neat-looking and well-arranged machine. It ran some hundreds of miles on the roads of Norfolk. It was intended to travel at the rate of ten or twelve miles an hour, on country roads and in all weathers, and was found to work very smoothly, and to be easily managed. The boiler and engine were placed in the rear; the engine, a two-cylinder vertical, was connected by a two-speed gear to the carrier wheel of a compensating gear on the countershaft, from which motion was transmitted to the rear wheels by chains. Like most of the steam carriages of the period it had a single steering wheel in front.

Other steam carriages which may be mentioned are those of Holt, 1866-1867; Blackburn, 1878; and Inshaw, 1881. Holt's carriage had a four-cylinder engine; Blackburn's was in the form of a dogcart, it was driven by a three-cylinder engine, acting through a variable speed gear and a gut driving band upon one of the rear wheels; Inshaw's took the form of an Irish jaunting car.[2]

In France nothing appears to have been done in the way of steam carriage building from the time of Deitz, whose vehicle was the subject of a trial made in 1839, before certain members of the French Institute, until about 1865, when the firm of Lotz at Nantes built one. This firm was in a fairly large way of business as builders

[1] *Steam on Common Roads*, 1891.

[2] Full accounts of these and other steam carriages will be found in Mr W. Worby Beaumont's Cantor Lectures, Society of Arts, 1896.

of traction engines, and some of their engines were used for hauling omnibuses in the streets of Nantes. It is said that several such passenger services were organised in different parts of France between 1850 and 1870. There was one between Paris and Joinville-le-Pont in 1869.[1]

Between 1873 and 1885 Amedée Bollée of Le Mans constructed a number of carriages; one of them, an omnibus built in 1880, partook in the Paris-Bordeaux competition of 1895, and was the only steam vehicle to complete the course. Another of Bollée's vehicles was used for a steam-omnibus service in Rouen in 1876, and a smaller carriage travelled from Paris to Vienna in 1878. This last was built very much on the lines of a modern petrol car; it had a vertical engine in front, a longitudinal transmission shaft, connected by means of bevel gearing to a transverse shaft, provided with differential gearing, which in turn transmitted the motion to the rear wheels by means of chains; and it had, like the other carriages of this maker, the Ackermann system of steering; the boiler was placed in the rear. The speed attained on the level was about twenty-two miles an hour.

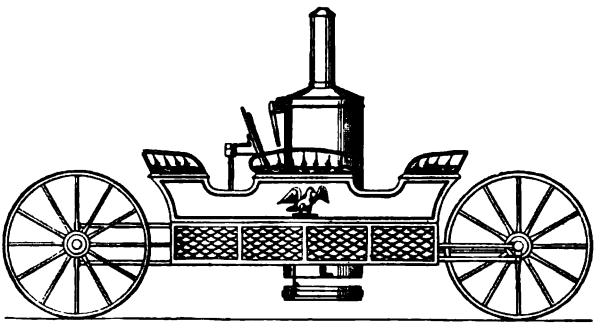
Turning to America, we find that in 1853 J. K. Fisher of New York built a small steam carriage with which a speed of fifteen miles per hour was attained on a good pavement, but the construction was too weak to stand the work of the roads. In 1859, having in the meantime been concerned with the building of two self-propelled fire engines, he again took in hand the steam-carriage problem, and one of his productions is shown in the illustration. Fisher used vertical boilers, and coupled the driving wheels to the engine shafts by coupling rods. His steering gear was of a special construction worked by means of a screw. The carriages worked successfully enough and attained good speeds, but the public refused to take them up.[2]

Joseph Battin of Newark, New Jersey, in 1856, built

[1] Lockert, *Traité des Véhicules Automobiles*, Tome ii.
[2] *Steam on Common Roads*, Young, Holley & Fisher, 1860.

a steam carriage fitted with a vertical boiler and oscillating engines, and in 1857 Richard Dudgeon of New York built his first carriage, which unfortunately was destroyed by fire at the New York Crystal Palace in 1858. It was constructed on the lines of a railway locomotive; in fact, most of the American experimenters of this period kept the locomotive in view. It weighed about one and a quarter tons, and hauled a light carriage at a rate of ten miles an hour on gravel roads. In 1866 he made another attempt, this time with a sort of steam wagonette.

The above were, it should be explained, not the earliest attempts at steam carriages in America. While Gurney



FISHER'S STEAM CARRIAGE, 1859.

and Hancock were at work in England experiments were being made in the United States by Harrison Dyer of Boston, Joseph Dixon of Lynn, Rufus Porter of Hartford, and many others, but little or nothing is known as to what they did.

A great many experiments have been made in America since 1866 with steam carriages and steam velocipedes. In 1882 Copeland of Philadelphia fitted an ordinary tandem tricycle with a vertical boiler, and a one and a half horse-power two-cylinder vertical engine. The boiler was fired with kerosene, the supply of which was regulated automatically according to the pressure of the steam in

the boiler. The machine worked very well, and about 200 were afterwards built like it.

The subject of steam velocipedes had not been neglected in England, and a good many experimental machines had been made in different parts of the country. Thus in 1877 Mr Meek, of the firm of Toward & Co., Newcastle-on-Tyne, made for himself a steam tricyle which worked very well.

Another steam tricyle was invented by Sir Thomas Parkyns in 1880, and in 1881, after considerable experimental work, a machine was produced which worked very successfully. The boiler was fired at first with methylated spirits, but this being found somewhat dangerous, petroleum spirit was used instead. The liquid was fed down a pipe to clusters of small bunsen burners provided with a fan blast.

"These burners could be easily used as a whole or in part, and the regulating valve was actuated by a rod attached to a small steam cylinder which automatically turned off the bulk of the burners as the steam pressure rose above 200 pounds. One small cluster always alight kept the others hot, and re-lighted them as the falling boiler pressure restored the supply of fuel. The first start was effected by placing about half a teaspoonful of methylated spirit in a cup under the central burner, which soon became hot enough to volatilise the benzoline and light up, when a handle attached to the blast fan enabled the requisite draught to be obtained to force the combustion, and the neighbouring burners rapidly joined in, until all twenty-one were in full play. The boiler was constructed of a hollow casting somewhat the shape of the letter A, but having a connecting bar joining the feet. The two horizontal tubes were pierced at right angles with series of five-eighth inch holes, into which were expanded a number of seamless copper tubes, bent like the letter M lying sideways, but with rounded angles. The open ends were expanded into the back holes of the above-mentioned casting, and the front ones (necessary for the expanding process) were then closed by screwed plugs. The top part

of the A frame formed a sort of steam chest, and at the apex was fixed a gun-metal block carrying steam valve, safety valve, tube to pressure gauge, and tube carrying steam to the cylinder to regulate the burners as above scribed. The copper tubes were capable of standing at least 1500 pounds pressure, so were perfectly safe at 200 pounds but even if one did burst the result would do little harm, owing to the small size and the immediate relief of pressure. As a matter of fact, no such event ever took place during the whole time of experiment and running. The engine actually employed was a little pair of double-acting horizontal cylinders, one and a half inches in diameter, and three and a half inches stroke, with ordinary slide valve and eccentrics, but no reversing gear. Rotary engines (an attractive idea) were quickly abandoned as voracious steam eaters ! and so the good old-fashioned pattern was adhered to. A little twelve-inch fly-wheel was used, although not absolutely necessary, but it certainly made the engine run more sweetly. A nicely-cut bevelled wheel of forty-five degrees was keyed on the main shaft, and geared into a similar wheel on a steel rod running to one of the rubber-tyred wheels of the tricyle. The driving-wheel end was geared down considerably, about four to one, and the bevelled wheel next to crank slid on a feather to throw the engine out of gear for pumping up only. One speed was therefore relied on, in which respect improvement was doubtless necessary.

"The condensing and boiler charging were perhaps the best points of the whole concern. Recognising the difficulty of getting a small pump to work really reliably, a small tank holding about a pint was fixed a little above the pump, so obviating any necessity for water raising of any kind. The exhaust steam passed into a tubular condenser, consisting of a large number of one-eighth inch tubes lying in a three-inch casing full of water. On condensation the warm (and pure) water ran by gravity into the little pump tank, and thence to the pump suction valve. It was thrown

back into the same supply tank through a valve attached to a copper ball, which, on rising and closing the aperture, compelled the feed to pass along an alternative pipe and past a clack valve into the boiler. The loss by evaporation of merely warm water was so trifling that the pump (always fully at work) kept the boiler practically at a uniform height, and a few teaspoonfuls every two or three hours was sufficient to keep the level entirely satisfactory, all joints and the pump plunger being, of course, in proper order. It only remains to explain the mode of keeping condenser cool. Another tank, holding about a gallon of water open to the atmosphere, contained a pump actuated by an auxiliary crank working by gearing from the main shaft at a slow speed. This pumped water into the outer shell of condenser, from which it issued at other end, heated by its work of condensing the exhaust steam in the little tubes round which it flowed. In this heated condition it fell into a tray formed in steps and fitted with a tangle of tinned thin wire, so as to present a very large surface which was blown somewhat strongly by a blast of cold air from another pressure fan driven by the engine from a grooved wheel and gut band. This breaking up of the hot water over a large surface, and blowing it strongly, cooled it with extraordinary rapidity, and it fell back cool into the pump tank, and was sent back to do its work over again." [1]

This machine was run with great success during the Stanley Show at the Agricultural Hall, Islington, and orders began to pour in upon the makers; but it was a question whether, having bought the machines, purchasers could legally use them upon the roads. Accordingly, a test case was arranged for, and Sir Thomas was taken before a magistrate, and, as Mr Bateman puts it, "charged with a breach of the Highways Acts, in using a carriage 'propelled by steam or other than animal power' at a greater speed than three miles an hour, with wheels less than four inches broad, and un-

[1] Mr A. H. Bateman in *The Autocar*, November 30, 1895.

protected by attendants, one carrying a red flag! In vain was it pleaded that no such thing as a steam tricycle had been born or thought of when the Highways Acts were passed, and that Parliament in its wisdom really could not have legislated for an article yet in the clouds, if anywhere, certainly not in existence in the United Kingdom. The magistrate held that it was not his business to discuss what Parliament meant or claimed; the wording of the Act included this particular incriminated vehicle, and the defendant left the court poorer by the sum of one shilling and costs. Appeal to the Queen's Bench speedily followed, and here it was hoped the matter would be fought out and the question argued really on its merits, but, alas! the judge declined to hear either argument or evidence, and made short work of the whole thing by the brief but too effective decision, 'Conviction affirmed.' It was useless to proceed with the scheme further. A few academic experiments were yet made, and then, not feeling disposed to throw good money after bad, the whole thing was dropped, much to the disappointment of many would-be possessors of the new 'autocar.'"

After this exposition of the state of the law the motor vehicle movement remained in abeyance in England until the passing of the Light Locomotives Act in 1896.

CHAPTER IX

ELECTRIC CARRIAGES

THE pioneer in the application of electricity to purposes of locomotion appears to have been an American blacksmith, Davenport by name, and a resident of Bandon, Vermont. Following the investigations of Faraday, a good deal of research was being carried on at this time in connection with electro-magnetic motors, and in various parts of the world several inventors were at work upon electro-magnetic carriages. Davenport, however, after seeing some lecture experiments with electro-magnets, seems to have worked out his motor and carriage quite independently. He constructed his carriage, which was adapted to run on a small circular railway, in 1836, and two years later it was brought over to London and exhibited at work. Before this date, however, such a carriage had been made in England. Sturgeon, in his *Annals of Electricity, etc.*, announced in the early part of 1837 that he had succeeded in propelling a boat and also a carriage by the power of electro-magnetism, but he deferred giving particulars until his models were in a more finished state. Sturgeon, it may be remarked, had made a rotary electro-magnetic machine in 1832.

Botto, an Italian, made a carriage at about the same date as Sturgeon.

The first electrical carriage made big enough to carry a passenger was that of Robert Davidson of Aberdeen. This was at work in 1839, and was capable of carrying

two persons when travelling over a rough wooden floor. The experiments looked so promising that money was forthcoming for the construction on the same plan of a railway vehicle to the full gauge, which was tried in September 1842 on the Edinburgh and Glasgow Railway with disappointing results. The car or truck measured sixteen feet in length by six feet in breadth, and weighed five tons. The battery was composed of fifty-nine elements, each made up of a plate of amalgamated zinc placed between two plates of iron; and measuring fifteen inches by twelve inches. The motors were mounted on the car axles; the armatures were composed of cylinders of wood, into the surface of which was inserted two series, each of three, longitudinal iron bars spaced at 120 degrees apart. The magnet cores were built up, the limbs being made hollow, and the winding was made of bundles of wire wrapped round with cloth to ensure insulation. A commutator was fixed on the axle for the purpose of directing the current into the magnet coils at suitable intervals. The maximum speed attained was four miles an hour.

The next project we read of is that of Uriah Clarke, whose carriage was at work during the year 1840 on a circular railway at an exhibition at Leicester. A Daniel's battery was used, and the carriage with the battery weighed sixty pounds; it would run alone at a considerable speed for two and a half hours. After the battery power had been increased, the carriage was able to draw behind it a train. The motor was of the reciprocating type.

Another model carriage, stated to have been four feet long, and fitted with wheels one foot in diameter, was made by George Little of Bristol in 1841. The motor consisted of two sets of six radiating arms, secured to the axle of one pair of wheels; on the ends of the arms were formed bars, extending parallel to the axle, which were of steel, and magnetised. Each set of arms rotated opposite a horse-shoe electro-magnet. The current was supplied to

the two magnets alternately, and was cut off as each of the rotating magnets came opposite to them.

In 1847 Professor Moses G. Farmer constructed and exhibited in America an electro-magnetic locomotive, which, with a battery of forty-eight Grove cells, pulled a little car carrying two passengers on a track eighteen inches wide.

Page of Baltimore in 1850 constructed an electro-magnetic locomotive which propelled a car with a dozen passengers at the rate of nineteen miles per hour on the Washington and Baltimore Railway.

All these carriages were self-contained; they carried their own supply of electrical energy. Hall of Boston in 1857 made a small electrical locomotive, to which the electric current was supplied from a stationary source through the rails. This appears to have been the first instance of an electric locomotive being supplied from a fixed power station.

The carriages described above were all propelled by primary batteries and magneto-electric machines. In 1871 Gramme discovered the reversibility of the dynamo electric generator, *i.e.*, that it could be used for converting electrical into mechanical energy, and in 1880 Faure improved the lead plate storage battery of Plante by coating the plates with lead oxide. Faure's invention was taken up by a company in France, who applied his storage batteries in conjunction with dynamo-electric motors for the propulsion of tramcars. A tricycle also was so fitted, and is said to have given good results, and a four-wheeled electric dogcart was ordered by the company from Jeantaud, but nothing appears to have come of this.

Professors Ayrton and Perry made an electric tricycle in 1882. They took an ordinary open-front machine, removed the pedals, and fixed a spur wheel on one of the road wheels. The motor was suspended under a seat platform, fixed above the axle, and a pinion on its spindle geared with the spur wheel. A platform suspended from

the axle and from the backbone carried the battery of Faure or Sellon-Volckmar cells. The motor weighed about forty-five pounds, and the battery about one hundred. The results did not promise commercial success, although they were interesting from a scientific point of view.

Radcliffe Ward commenced his experiments with electric road carriages in 1886. He first built a cab which, in the year 1887, was running about Brighton, and answered fairly well. The storage battery consisted of twenty-eight cells, and was slung on a tray beneath the vehicle; the motor was mounted below the driver's seat, its shaft carried two friction pulleys, one half the size of the other, which geared with two loose pulleys on an intermediate shaft; this in turn drove the road wheels by a belt; either of the loose pulleys could be connected to the shaft, according to the speed required, by means of clutches. The total weight of the vehicle was twenty-five hundredweights, and it attained a speed of seven to eight miles an hour. An electric omnibus next engaged Mr Ward's attention. This was completed, and made its first trip in the streets of London in 1888, and it subsequently covered over 5000 miles altogether; its speed was about seven miles an hour.

Magnus Volk, of the Brighton Electric Railway, in 1887 built an electric dogcart which became very well known in the streets of Brighton. This had a battery of sixteen small accumulators under the seat. The motor was suspended on hangers under the body, and drove one of the rear wheels by chain gearing and a countershaft; it was rather small, only half horse-power, but on asphalt roads a speed of nine miles an hour was attained, and on soft macadam one of four miles. Volk subsequently joined Immisch & Co., and built, in 1888, an electric dogcart for the Sultan of Turkey. What the Sultan did with it is not known. The car had a battery of twenty-four cells weighing seven hundredweights, and the charge is stated to have been sufficient to propel it at the rate of ten miles an

hour for five hours. The total weight of the car, including the battery, was eleven hundredweights. The motor, of one horse power, was placed under the body, and drove direct by chain to the rear wheels.

Soon after this, Aboilard, Blanche and De Graffigny were at work upon electric tricycles. De Graffigny went back to the primary battery, but his results were not very successful.

The first electric carriage that can in any way be regarded as approaching a satisfactory issue was that made by Pouchain in 1893. It was a six-seated phaeton on four wheels, and had a battery of fifty-four elements, each of three plates, a Fulmen positive and two Dujardin negatives. The capacity of the battery was seventy ampère-hours. The motor was of the Rechniewski type, shunt wound, power about 3500 watts, and normal speed 1650 revolutions per minute; it was geared to the rear axle through an intermediate shaft and chain gearing. The speed of the car was varied by changing the grouping of the cells, and this was effected by rotating a cylinder which carried suitable contact pieces. The battery weighed 1100 pounds, the motor 240, and the total weight of the carriage was one and a quarter tons.[1]

In the same year Sarcia and Moussette were also conducting experiments with an electric vehicle for the Societé du travail électrique des métaux; and in America Cummings was at work in the same direction.

Blumfield and Garrard in 1894 brought out a four-wheeled vehicle built on cycle lines, and with pneumatic tyres to the wheels. A variable speed gear was used, and the motor worked at a constant speed.[2]

[1] *Les Automobiles Electriques*, par Gaston Sencier et A. Delasalle, 1901.

[2] From an illustrated account in *The Autocar* of November 9, 1895, it appears that this carriage had a body to seat four mounted by means of spiral springs on a tubular frame, and ran upon twenty-four inch wheels fitted with four-inch pneumatic tyres. The motor was mounted in about the centre of the frame, with its shaft extending lengthways of the car. The shaft carried a friction roller which engaged with a disc on an intermediate spindle which was geared by a chain to the differential gear on the rear axle. The motor

In the same year Bersey produced an electric parcels van which ran for several months in the city of London.

There were at this time three companies in existence in London having for their object the building of electric vehicles, viz., Ward's Electrical Car Company (founded in 1888), the Pioneer Electrical Car Company, and the Electrical Road and Street Car Company founded to take over the business of Clubbe & Company who had built some electrical vans which promised well. The Locomotives Acts, however, stood in the way of the free use of any form of motor vehicle at this time, so that, even if the construction and working had been perfect, which of course was not the case, it was impossible to build up an industry.

In the Paris-Bordeaux competition of 1895 Jeantaud entered a carriage which covered about 350 miles with frequent relays of batteries. Carli, an Italian inventor, entered for this competition but did not run. In the Chicago *Times-Herald* contest in the same year there were two electrical vehicles, those of Sturges, and Morris & Salom. Sturges employed a motor for each driving wheel, thereby dispensing with the differential gear. In 1896, on the occasion of the run to Brighton to celebrate the passing of the Light Locomotives Act, Vaughan-Sherrin appeared with an electric carriage. In the following year electric cabs were placed on the streets of London, but this and other schemes in various other places were soon dropped. The electric carriage had not then at all events reached the stage of commercial success.

was intended to run at a constant speed, and to permit of variation in the speed of the car the shaft of the motor was made movable lengthways, thus varying the radius at which the friction roller engaged with the disc and so the speed imparted to the latter. The battery, composed of twenty-four cells, was carried under the seats, it weighed about 500 pounds, and was estimated to be sufficient for a run of seventy to eighty miles. The complete vehicle with the accumulators weighed about half a ton. A trial trip was made from Coventry to Birmingham, eighteen miles, in June 1894, and was performed successfully, a speed of ten miles per hour being maintained over many parts of the road. A day or two afterwards the vehicle was run about the streets of Birmingham.

CHAPTER X

THE MODERN REVIVAL

In the preceding chapters the attempts made to produce a satisfactory motor vehicle have been followed up to about the year 1880. It has been shown that from 1860 onwards the problem had been pursued continuously, now in one part of the world, then in another; that when one inventor relinquished it, another was found to carry on the work; now in the form of a motor omnibus or coach, then in that of a private carriage, and again in that of the velocipede, for beyond question, the application of mechanical power to common road vehicles has proved a most fascinating problem to the inventor.

But practically the only motor then available for these efforts, the only motor that had approved itself in ordinary engineering practice, for locomotives, and for navigation, was the steam engine, and the steam engine, or rather its essential adjunct the boiler or steam generator, as then constructed, however well it might suit the traction engine, did not lend itself to application to lighter vehicles. Even in the much easier task, the production of a steam tramcar, the difficulties were found to be too great to permit of a really satisfactory result. It was difficult to prevent the escape of smoke and steam into the atmosphere; the stoking of the boiler with solid fuel was troublesome and required constant attention in order to maintain the required steam pressure; the dust of the fuel, the heat of the boiler and the smoke were all sources of discomfort to the traveller. Then again there was the necessity for stopping

at frequent intervals to replenish the supplies of fuel and water, and to adjust the machinery. From one point of view, it is true, all these were minor difficulties, they did not affect the ability of the machine to progress along the road; a motor car could be made to go, and indeed to go at fairly high speeds, and it is conceivable that an engineer might find a certain amount of interest or even of pleasure in the possession of one of these earlier steam cars, and for the gratification it gave him as an engineer might be content to forego or even to ignore the absence of the comfort usually associated with horse-drawn vehicles. Not so the ordinary traveller; to him the question of the mode of propulsion was of secondary importance as compared with that of comfort of travelling and the certainty of arriving at his destination in some definite time. Of the cars of this period it may be said fairly that no unbiassed person could expect the public to take to them with pleasure, and it is not surprising that in all these years the subject received little or no consideration from the public, and that the efforts of the various inventors were looked upon with a sort of benevolent pity.

About the year 1894, however, a marked change came over the scene, and carriages were produced which, although far from perfect, gave results such as compelled first respectful and then favourable consideration. This, the beginning of the motor-car movement which has to-day attained such considerable dimensions, was undoubtedly due to the application of an explosion or internal-combustion motor, worked by petroleum spirit or petrol, the invention of the late Herr Daimler. Not, be it understood, that there was any novelty in the use of liquid hydrocarbons, such as benzine, gasoline, etc., instead of gas in explosion engines, or that the idea of applying an explosion engine to a motor car now presented itself for the first time. Medhurst, in 1800, had patented an engine to be worked by gunpowder or other explosive and its application to a carriage; Lenoir, in 1862, had tried a gas engine on a vehicle; Hardaker

had patented a bicycle so propelled in 1880, and in the same year Lawson invented a gas motor tricycle which was propelled by gas prepared from gasoline and stored in a receptacle carried on the machine; in 1883 Delamare-Debouteville and Malandin made a gas motor tricycle, and early in the following year they patented the use of petroleum spirit for working it.

Daimler's motor, however, in the form which it had attained in the year 1889, was such as to hold out some promise of success in connection with the propulsion of road vehicles. This prospect appealed to certain engineering firms in France, to whom must be ascribed the credit of bringing the motor car within the regions of success, and they took up the matter with great vigour. One result of this was that in a few years the Daimler motor had been completely metamorphosed, so that it is somewhat difficult to trace out any of Daimler's original ideas in the modern petrol motor. It is nevertheless fitting that his name should remain associated with it; the pioneer work was certainly done with the engine as it had been evolved in his brain. He broke ground which the French engineers carefully tilled; it was the promise showed by his motor that induced vigorous work upon the subject of the petrol car, the success of which reacted upon the steam and electric cars, and gave renewed life and hope to their projectors.

Still there is a great deal in the time factor; the old saying that an inventor may be born before his time is to a large extent true. As a rule inventions do not develop into practical results unless time and circumstances are favourable. By the year 1894 the increasing use of the bicycle had done much to cultivate a liking for travelling upon the high roads, and people were in a measure ready for some new means of doing so. In England, of course, the state of the law rendered abortive any attempt at the application of motors to vehicles, otherwise Butler's petrol tricycle, referred to later on, might have been worked out to a successful issue. Fortunately the engineers of France

were not hampered in that way, and the new movement had a fair field for its start in that country.

Daimler

Towards the end of the year 1884, or at the beginning of 1885, Daimler[1] had contrived a motor to be worked by gas or petroleum vapour or spray, which is the first of his inventions that demands consideration in connection with motor vehicles. This engine worked on the Otto or four-stroke cycle, and its leading feature was the introduction into the cylinder, both before and after the admission of the main charge, of additional charges of either the combustible mixture or of air. For this purpose the crank chamber was closed in and fitted with a valve, through which the mixture, or air, as the case might be, was drawn in as

DAIMLER'S BICYCLE, 1886.

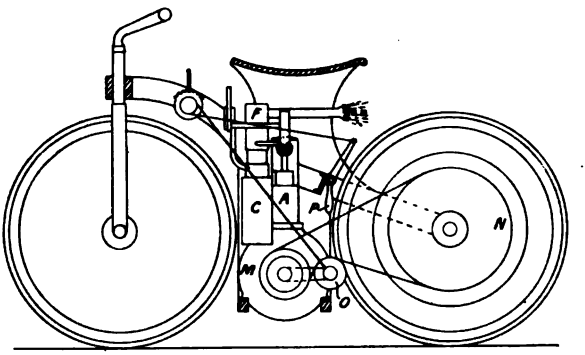
[1] Gottlieb Daimler was educated as a mechanical engineer. In 1872, after having spent several years in some of the leading engineering works in England, he returned to Germany to take up the position of technical director of the Otto gas engine works at Deutz, which, under his management, became a very large undertaking, and acquired a world-wide reputation. In 1882 he resigned his connection with that establishment, and retired to an estate which he had acquired at Cannstadt. Here he commenced experimenting on small gas and oil engines, and their application to road vehicles. Later on his work led to the formation of the Daimler Motoren Gesellschaft. He died in 1900 at the age of sixty-six.

the piston moved away from the crank shaft. When the piston commenced its return stroke, the valve closed and the contents of the crank chamber were compressed; as it approached the end of the stroke, a valve fitted in the piston opened and allowed the compressed gas to rush through into the working end of the cylinder. The gas introduced in this way at the end of the working stroke served to assist in driving out the spent charge. The valve closed automatically as the piston moved away from the crank shaft. The crank pin was fixed between a pair of discs, made heavy to serve as fly wheels, one of which had a cam groove cut in its face for operating the exhaust valve.[1] The inlet valves opened by the pressure of the atmosphere and the ignition was effected by an incandescent tube. The cylinder was cooled by a current of air set up by a fan.

This engine Daimler proceeded to apply to a bicycle which was completed and tried in November 1886. The machine, which is still in existence and has been exhibited in Paris and in London, has a most crude appearance. It is, however, well worthy of examination, particularly in view of the rapid development of the motor bicycle within the last few years. The engine, placed vertically between the wheels, is supported in a frame constructed on the lines of the old "boneshaker" and drives the rear wheel by a band and pulleys. The band is tightened or loosened, to connect or disconnect the engine, by a jockey pulley worked by a small handle in front of the rider; a brake is applied automatically to the rear wheel when the band is slackened. The top of the engine casing forms the saddle; there are no pedals, but a foot rest is provided on each side near the ground, and small steadying rollers are mounted

[1] The engine was governed by preventing the opening of the exhaust valves when the speed rose above the normal, so that the cylinder being full of gas, no fresh charge was drawn in upon the suction stroke. This was effected by means of a governor, mounted on the disc, and coupled to a switch in the cam groove; when the speed got too high, the governor deflected the shuttle on the end of the valve stem into a circular part of the groove, so that the disc in rotating ceased to impart the to-and-fro movement to it.

by means of springs on the foot rests. The exhaust is discharged under and behind the saddle; it may be used to warm up the carburetter. In the carburetter, used to produce the mixture of air and combustible vapour, the entering air is caused to bubble through a volume of the liquid maintained at a constant depth in a chamber floating in the main supply reservoir. This type of carburetter



A. Engine. M, N. Pulleys for band. O. Jockey Pulley.
C. Carburetter. F. Silencer. P. Brake.

DAIMLER'S BICYCLE, 1886.

remained in use until 1893, when it was supplanted by the now familiar float-feed spray carburetter.

Following up the application of his motor to road vehicles, Daimler constructed a four-wheeled vehicle to seat four; the engine was placed in the body of the car with the cylinder standing up through the footboard of the back seat; the rear axle was geared to a counter shaft placed behind and driven by belting from the engine. The results were not very satisfactory, and Daimler appears subsequently to have devoted himself mainly to the improvement of the engine.

The improved engine which followed in 1889 was that which really set going the motor-car movement. It became

known as the V-engine from the fact that it had two cylinders set like the limbs of the letter V. The two pistons were coupled to a single crank, working in a closed chamber, which, as in the engine of 1885, was used to supply a part of the charge to the cylinders through valves in the pistons. The means for governing were also improved.[1]

At this stage the firm of Panhard & Levassor acquired Daimler's patent rights for France and Belgium, and it was this engine which they and the firm of Les Fils de Peugeot Frères first applied to motor cars. The plan of taking part of the charge from the crank chamber was soon abandoned, but in other respects the V-engine was used with but little modification for some years, and the cars presented by the above-named firms in the Paris-Rouen competition in 1894 were fitted with engines of this type. In the year 1895, however, Panhard & Levassor brought out a new type, and in 1896 the Peugeot firm followed with a motor of their own devising.

Benz

Carl Benz of Mannheim in 1885 built a small three-wheel motor carriage, fitted with a gas engine, the design of which exhibits very careful thought and presents several features of interest. The engine, to be worked by the vapour of ligroine, benzine, or the like, was placed behind the seat and well above the axle of the rear wheels. The crank shaft, placed quite at the back of the car, was arranged vertically so that the fly wheel revolved in a horizontal plane. This plan was adopted with the idea of

[1] The exhaust valves were, as before, worked by means of cam grooves on one of the crank discs, but a modified form of governor was now employed to break the connection with the valve stems and to make it again as the speed exceeded the normal and fell to it again. In the specification of the patent for this engine Daimler describes other arrangements of two-cylinder engines. In one, the cylinders are to be placed side by side; in another, on opposite sides of the crank shaft, with the pistons coupled to opposed cranks.

nullifying the gyrostatic effect of the heavy revolving mass upon the steering of the vehicle. A short horizontal shaft was geared to the upper end of the crank shaft by bevel gearing and drove a countershaft placed under the floor of the car, in front of the seat, by a belt and pulleys; the ends of the countershaft were geared to the road wheels by chains. The countershaft was in two lengths, connected by a balance gear; it carried fast and loose pulleys, so that by shifting the belt from one to the other the engine could be caused to drive the car or allowed to run free. The handle for shifting the belt served also to apply a brake after the engine had been disconnected.

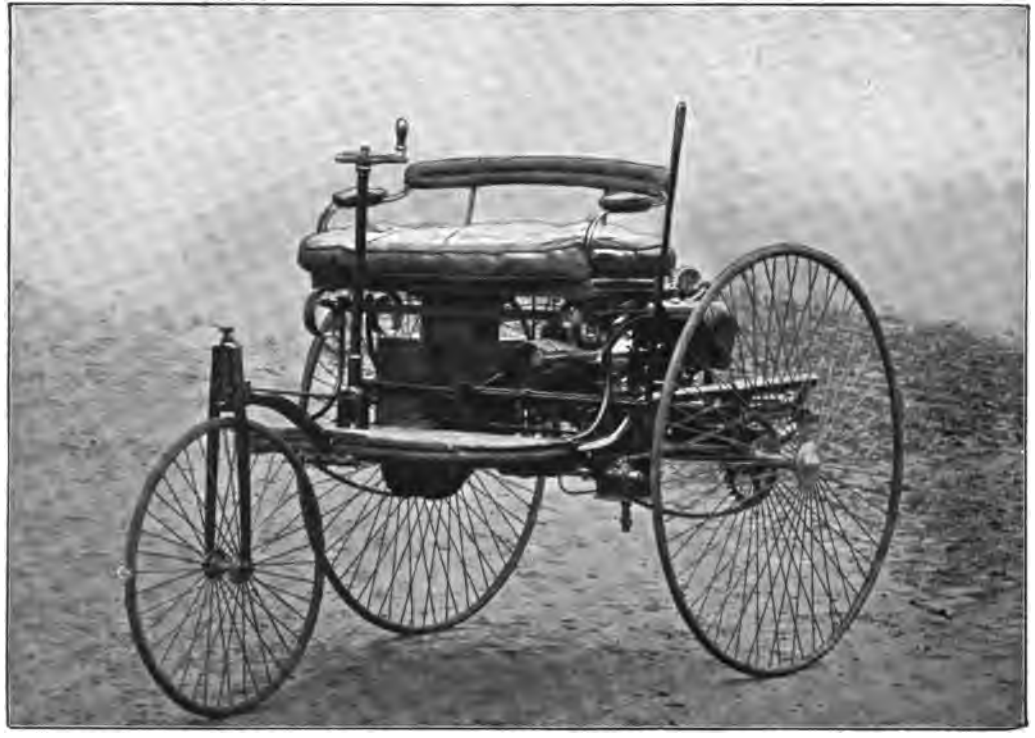
The engine cylinder was cooled by a water jacket.[1]

A more perfect carriage was built in the following year; the transmission gearing was modified, a variable-speed device was introduced, the brakes were connected to the clutch gear so that they could not be applied without first disconnecting the engine. The clutch lever was also connected to a cock on the gas supply pipe so that the opening through this varied with the position of the lever, thus when the car was stopped the supply was automatically reduced to the amount required to run the engine idle. This vehicle attained a speed of ten miles per hour. A third car, made in 1888, also mounted on three wheels, could cover twelve to fifteen miles per hour.

BUTLER

Turning from the German inventors, Daimler and Benz, we come to an Englishman, Butler, who at about the same period was, like them, at work in attempting to solve the motor-car problem with the aid of an engine worked by mineral hydrocarbons, but, unlike them, had

[1] In the specification of his patent for this car Benz, in order to reduce the amount of cooling water required, proposed to allow the water to evaporate in the jacket and to condense the vapour in a tubular condenser placed above the cylinder. In the carriage as built this condenser was not used.



THE BENZ CARRIAGE, 1885.

to contend with restrictive legislation, which in the end led to the abandonment of his promising project. Butler appears to have been directing his attention to the subject as early as 1884, and is said to have exhibited drawings of his plan at the Stanley Show in that year, and at the Inventions Exhibition in the following year, but the first definite record of his work is to be found in the specification of his patent of 1887 for "Improvements in hydro-

BUTLER'S TRICYCLE, 1887-1890.

carbon engines and in the method of their application for the propulsion of tricycles and other light vehicles." Between that date and 1890 the tricycle shown in the accompanying illustration was built, but as the inventor, writing[1] in 1890, very mildly puts it, "the authorities do not countenance its use on roads, and I have abandoned in consequence any further development of it."

In this machine, which is still in existence, the two front wheels are steering wheels, and the rear wheel is driven by a two-cylinder engine. Originally the wheel was mounted directly upon the crank shaft, with a crank on each side of it, but after trial this direct drive was given up and an epicyclic gear train, giving a reduction of six

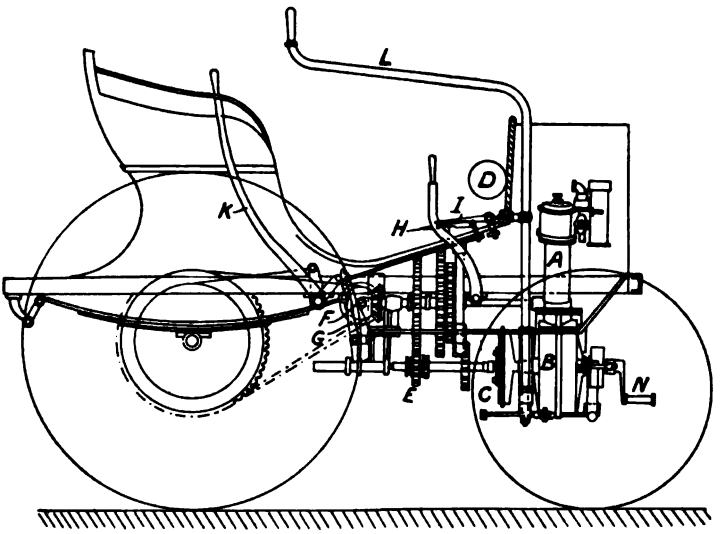
[1] In the *English Mechanic*, December 12, 1890.

to one, was introduced between the shaft and the wheel. The motor also was altered, and the Wimshurst machine used in the first instance for the electric ignition was replaced by a battery and coil. The engine was worked by air carburetted by the spray of benzoline or similar petroleum product, and the cylinders were cooled by water which was circulated through a radiating hood carried over the driving wheel to form a guard. The speed was controlled by a throttle valve, and the machine was stopped by lifting the driving wheel off the ground by means of two small rollers forced downwards by a pedal. The wheels were thirty-two inches in diameter and were fitted with rubber tyres. The machine weighed 280 pounds, and is said to have worked very satisfactorily.

Panhard & Levassor.

The premier position among builders of motor cars must be assigned to the firm of Panhard & Levassor of Paris. They were one of the first firms to engage in the manufacture of petrol cars (apart from experimental productions), and to their clearness of insight into the requirements of the case, their persistence and energy, is largely due the successful issue of a movement which at its initiation was held in so many quarters to be doomed to failure. In 1889 Panhard & Levassor, who were in business as engineers in Paris, acquired the French and Belgian patents for the Daimler motor. They commenced building the engines for industrial purposes and for launches, but very soon the suitability of the new motor for locomotion on common roads suggested itself, and possibly they had been made acquainted with Daimler's experiments in that direction. At all events, in 1891 they brought out a neat-looking car propelled by petrol. They must have met with a fair amount of success at the outset, for shortly afterwards it appears that ten such cars had

been built, and by the year 1894 the firm had turned out about ninety. They had up to that time made about 350 engines, of which eighty had been supplied to the Peugeots. These early cars had very small engines, only about one and a half horse-power, and were geared to give speeds of three, six and ten miles per hour. Towards the end of 1892 Panhard & Levassor were constructing cars in



A. Engine Cylinders.
B. Crank Chamber.
C. Clutch.
D. Petrol Tank.
E. Change Gearing.
F. Transverse Shaft.
G. Clutch Lever.
H. Pedal for operating Lever.
I. Pedal for Brake.
K. Change-speed Lever.
L. Steering Lever.
N. Starting Handle.

PANHARD AND LEVASSOR CAR OF 1891.

four types, *i.e.*, a dogcart to seat four, a wagonette, a brake to seat six, and a small vehicle to seat two, but which might be fitted with an extra seat at the back.

From the first these carriages were distinguished by some of the leading features which they still retain, and have become common with other constructors. Such,

for instance, are the position of the engine in front of the car, the system of gearing and the driving of the rear wheels by chains.

In the Paris-Rouen contest in 1894 this firm had four cars running, all fitted with V-type Daimler motors capable of giving off about three horse-power and enclosed in a box in front of the car. The ignition was effected by platinum tubes heated by petrol lamps. The cylinders were cooled by water circulated through a cooler, below the body of the car, by means of a centrifugal pump. There were two petrol tanks; one in front, of a capacity suitable for a run of about fifty miles, and another behind, which brought up the total capacity to enough for 175 miles. The mean consumption of petrol was about three gallons per hundred miles.

The crank shaft was, as now, mounted lengthways in the car and coupled to a shaft in the same line by means of a friction clutch; this latter shaft was geared to another placed above it by a change-speed gear of the sliding-wheel type as at present; but the transverse shaft carried two loose bevel wheels in gear with the pinion on the change-gear shaft, and either of these might be fixed by means of a sliding claw clutch, according as the car was required to move forward or backward. The tranverse shaft was coupled by a single chain, in about the centre of the car, to the rear axle, which was fitted with compensating gear.

The front axle had pivoted ends to carry the wheels on what is now well-known as the Ackermann system; they were controlled by a lever placed on the left-hand side of the driver. The other handles for controlling the car and the pedals were all brought into convenient positions for the driver. The clutch pedal was coupled to the brake lever, so that the brake could not be thrown on without uncoupling the engine. The clutch was a cone friction clutch of special construction; the male member consisted of two concentric parts separated by springs; the inner part,

the surface of which was formed at an acute angle, first came into contact with the female cone and commenced the drive, allowing a certain amount of slip; as the clutch lever was advanced, the outer part was pressed into action and the whole power was transmitted. This construction was adopted in order to secure the gradual engagement of the engine with the transmission gearing.

The road wheels were of wood with iron or with rubber

PANHARD AND LEVASSOR CAR, 1894.

tyres; the use of rubber tyres had been begun a year or two before, but the iron tyres had not been displaced altogether at this time.

Such, briefly, was the construction of the Panhard & Levassor car in 1894. The new Daimler carburetter was being tried. It is not clear whether it was fitted on any of the cars sent in for the Paris-Rouen contest, but it certainly appeared, together with other features of novelty, in the Paris-Bordeaux race in the following year. After *Le Petit Journal* contest the firm applied themselves to reducing the weight of the propelling mechanism, and the engines were run at a higher speed and given a somewhat

longer stroke, thus increasing their capacity by about one-sixth. At the same time an entirely new type of engine was produced; it was somewhat more powerful than the earlier engines, giving off about four horse-power, but it weighed only about half as much per horse-power, took up less space, and was more convenient to fit in the carriage. The chief point of difference was that the angular position of the cylinders was given up and they were placed vertically one behind the other. The fastest car in the race of 1895 had engines of this type. It was adapted to carry two persons, weighed about twelve hundredweights, and was geared to run at six, twelve and eighteen miles per hour. Another car, built to carry five persons, had a four-cylinder engine and weighed about thirty-five hundredweights. In addition to introducing the new type of engine, which was termed the Phœnix, improvements were effected in the gearing. In 1894 all the change wheels had been made of bronze; now one set was made of bronze and the other of steel, and the gear was enclosed in a box. The compensating gear was carried on the transverse shaft, and each road wheel was driven by a separate set of chain gearing as is the practice to-day.

PEUGEOT

About the year 1890 another French firm of engineers, Messrs Le Fils de Peugeot Frères, of Valentigney (Doubs), commenced building motor cars fitted with petrol engines. They had previously constructed a small steam vehicle, fitted with a Serpollet boiler, which is said to have been shown at the Paris Exhibition of 1889. M. Armand Peugeot was not satisfied with this machine, and when M. Levassor showed him a small car fitted with the Daimler motor, he was at once won over to petrol and made arrangements for obtaining a supply of the engines.

In the Paris-Brest bicycle race, organised by the proprietors of *Le Petit Journal* in 1891, a small car made by the Peugeot firm followed the course and attracted a considerable amount of attention. It is estimated that it made a journey of over a thousand miles almost without interruption, as it was driven from the works at Valentigney, away on the borders of Switzerland, direct to Paris, where it arrived just in time to start with the bicycles.

By the year 1894 the firm had made about eighty

PEUGEOT CAR, 1895.

motor cars. As large makers of bicycles their cars naturally followed cycle lines to some extent. They had bicycle wheels mounted on ball bearings, and frames built up of steel tubes. The engines were Daimler's, supplied together with the clutches by Panhard & Levassor, and the change gear was of the same type as that adopted by the Paris firm, but the Peugeots placed the engines in the rear of the car instead of in front. The car of 1891 was driven by a two-horse-power engine, geared to give speeds of three, six, nine and twelve miles per hour, and had seats

for four persons. By 1894 they had increased the power of their engines, and in 1896 they produced a new type of engine which was finished just in time for the Paris-Marseilles race of that year. The present firm was founded to take over the motor-car business from the original firm in 1896. They have works at Audincourt and at Lille.

ROGER

Just as Panhard & Levassor had taken up the Daimler motor so had M. Roger of Paris taken up that of Benz, and he appears to have embarked upon the construction of motor cars at about the same time as that firm. Here again the French engineer simplified and improved the original machine. The Benz motor for industrial purposes was essentially one which worked on the two-stroke cycle. M. Roger very soon induced Benz to revert to the more usual four-stroke cycle, and substituted high-tension electric ignition for the magneto system of Benz.

In the Roger carriages a single-cylinder horizontal engine was used with the engine mounted above the rear axle and the crank shaft behind it and horizontal, not vertical as in the original Benz cars. Power was transmitted from the crank shaft, which made about 300 revolutions per minute, to a countershaft fitted with compensating gear, by means of belts and pulleys arranged to give two speeds, *i.e.*, three and twelve miles per hour. Intermediate speeds were obtained by varying the explosive mixture. The countershaft was connected to the rear wheels of the vehicle by chains, one on each side. The front axle was pivoted on the Ackermann system.

The Roger carriages attracted considerable attention by their neat appearance, their stability and comparative freedom from vibration. At the end of 1894 it appears

that there were fifty of them at work in France and abroad. They were at this time fitted with three-horse-power engines, and a carriage for four persons *vis-à-vis* weighed about fourteen hundredweights. For the Paris-Bordeaux race in 1895 M. Roger increased the engine power to four horse-power.

The Paris-Rouen Contest, 1894

By the year 1894 interest in motoring had developed so far that the proprietors of *Le Petit Journal* organised a competition for carriages to be propelled without horses. The trials were held in July 1894, and stand out as a landmark in the history of the subject. The announcement of the competition brought forward 102 entries, comprising thirty-eight petrol, twenty-nine steam, five electric, and five compressed-air carriages. The remaining twenty-five entries related to vehicles propelled by various unclassified means, and some of them no doubt existed only as schemes on paper—such probably was the carriage to be propelled by the weight of its occupants. Only a small proportion of the entries actually appeared at the preliminary test, a run of thirty miles in the neighbourhood of Paris. At the final trial, a run from Paris to Rouen with a stop at Mantes, a total distance of 126 kilometres, say seventy-eight miles, over a good but hilly road, twenty-one carriages presented themselves. Of these, fourteen, produced by seven different makers, were driven by petrol motors, the other seven were steam carriages. The entire absence of the electric or any other form of carriage is remarkable. The competing carriages were of various forms—brake, wagonette, phaeton, etc.—and carried, for the most part, four persons, but one of the steam cars carried ten and another eight. The object of the trial was to determine the carriage which presented, in the most marked degree, the characteristics of freedom

from danger, ease of management, and lowness of cost on the road. It must be understood that the competition was in no sense a race, and, in fact, it was expressly provided that no credit would be given for speeds higher than twelve kilometres, say seven and one-half miles, per hour. Of the petrol carriages the whole fourteen completed the journey, a most remarkable circumstance in view of the lack of experience of many of the makers and drivers. Indeed, in the case of one of the Panhard cars, the stops on the road necessitated by attention to the motor amounted in all to but twenty minutes. The steam carriages were not equally successful, as four of them failed to reach Rouen. That of the Comte de Dion, however, did very well, ascended the hills in fine style, and although it took about the same time over the journey as the fastest petrol car, its average speed was higher, as through losing his way the driver took it over a longer course.

However, as stated above, no credit was given for speed above the limit of twelve kilometres per hour, and the first prize was divided between Messrs Panhard & Levassor and Messrs Peugeot. The former firm had four carriages running, the latter five, all driven by the Daimler petrol motor. Other petrol carriages to which prizes were accorded were those of Messrs Vacheron, Lebrun and Roger. The steam carriages of De Dion, Bouton & Co., Le Blant, and Scotte were also deemed worthy of prizes, and the steam tricycle of Roger de Montais[1] of honourable mention. The other competitors whose carriages completed the journey were De Bourmont (petrol), Gautier (petrol), and Archdeacon (steam). The Vacheron and Gautier carriages were on similiar lines to the Panhard & Levassor, and the Lebrun to the Peugeot.

A petrol carriage from which a good deal was expected, but which failed through the breakage of a

[1] This machine, which failed to complete the journey to Rouen, had the boiler behind the front wheel and a two-cylinder engine under the seat.

spring at the preliminary trials, was that of M. Tenting of Paris. After repair this carriage performed the journey to Rouen in seven hours.

Tenting appears to have been at work fairly early on the problem, as he is said to have completed his first carriage, a four-seated vehicle, about the beginning of 1891. He was a maker of gas engines and fitted his car with a horizontal motor of his own design, working on the Otto cycle. This was placed over the rear axle, and had two cylinders, arranged side by side, the pistons of which worked on to the same crank pin. The crank shaft carried a variable-speed friction gear, which drove the rear axle by chain gearing. This first vehicle had a swivelling forecarriage, but in his second attempt, a six-seated phaeton, Tenting used the Ackermann system for his front axle and steerage; he also modified his engine by arranging the cylinders in the same manner as the Daimler V-engine, but on their sides.

Having dealt with the petrol carriage as it was at this period, we may turn to the consideration of its chief rival, the steam carriage.

The De Dion-Bouton Steam Carriages

The Comte de Dion and his partners, MM. Bouton and Trepardoux, commenced their attack upon the motor-car problem in 1883. They took the motor which was then the best known, and the working of which presented no difficulties and required no experimental research in itself—the steam engine. The production of a satisfactory steam generator was, however, a difficult matter, and it was not until 1884 that their first vehicle appeared; it was a tandem tricycle in which the second seat was replaced by the motor and generator. The motor was of one horse-power, and the machine is said to have attained a speed of eighteen and a half miles

per hour. In the following year another tricycle was brought out; it had the motor and generator between the two front wheels, which were used for steering, and the seat above the rear driving wheel, which was worked directly by a tandem compound engine. Upon this machine M. Bouton covered one kilometre per minute. Between this date and 1893 De Dion, Bouton and Trepardoux, in association with M. Merrelle, built a number

DE DION-BOUTON STEAM CAR, 1889.

of vehicles of different types, including a small carriage to seat four, propelled by two tandem compound engines, which is shown in the accompanying illustration. Its weight was over thirteen hundredweights. De Dion and Bouton then turned their attention to another type of vehicle, and produced the steam tractor which figured in the Paris-Rouen contest of 1894.

The steam tractor was an independent four-wheeled vehicle or locomotive which took the place of the fore-carriage and front wheels of an ordinary vehicle, and in which all the machinery was mounted. The boiler was

placed in front and surrounded by the fuel bunkers; the engine, compound, was in the rear, and the water tank was under the driver's seat. The front steering wheels had rubber, and the rear driving wheels iron tyres. The boiler pressure was 200 pounds per square inch. The tractor weighed about one and three-quarter tons empty, and two and a half tons charged. It carried a supply of water sufficient for a run of about twenty miles, and of fuel for about sixty. The driving wheels ran upon hollow

DE DION-BOUTON STEAM TRACTOR.

axles, through which passed the driving shafts which were connected to the rims of the wheels by driving arms and were coupled by universal joints to a shaft driven by toothed wheels from the engine shaft. The boiler was, as indicated above, of special construction. It may be said to have consisted of four vertical concentric cylinders, which formed two annular water and steam chambers separated by a third annular chamber, into which the flame and gases ascended from the fire grate and across which passed a number of inclined tubes connecting the inner and outer water and steam chambers. The fire grate was inside and at the bottom of the outer chamber; the

bottom of the inner chamber was at some distance above it. The fuel was supplied from the top through the central cylinder. The exhaust steam was passed through a coil under the grate to render it invisible, and discharged into the chimney. This vehicle together with another of a new type were entered for the Paris-Bordeaux race in 1895. The new vehicle until it met with a mishap on the outward journey worked very well and ran at a higher rate of speed than the Panhard & Levassor carriage which came in first. In the Marseilles-Nice-Turbie race, 1897, a De Dion-Bouton steam carriage came in first with flying colours, but since then, until the successes of the Serpollet cars in the present year, no steam carriage has been able to compete with the petrol vehicles in point of speed.

The Scotte Steam Carriage

The vehicle entered by M. Scotte for the Paris-Rouen contest was an omnibus for ten or twelve passengers. The boiler, of the Field type, was placed in front. The engine was a two-cylinder reversing engine. Both stoker and driver were placed in the front of the car. The combination made a simple, strong and easily-controlled vehicle, well adapted for carrying a number of passengers. In 1895 M. Scotte had two services of steam omnibuses at work in France, in which it appears that the motor vehicle with seats for twelve persons hauled another carriage capable of holding twenty-eight at an average speed, on ordinary roads, of seven and a half miles per hour. The motor vehicle, including six hundredweights of fuel and twelve hundredweights of water, weighed four tons, and the trailer weighed about one and a half tons. So that the dead weight moved amounted to about 310 pounds per passenger. Since that period "les Trains Scotte" have become well known in different parts of France and have earned a good reputation for themselves.

The Le Blant Steam Carriage

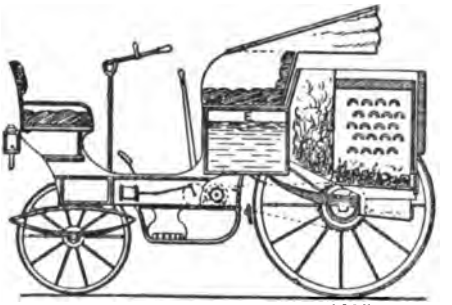
Like the preceding, M. le Blant's carriage was built to carry a large number of passengers, but it had the boiler behind, and the stoker was necessarily separated from the driver, who was in the front of the vehicle. The weight, including fuel and water, was three and a half tons, and there were seats for nine passengers. The engine was a three-cylinder horizontal engine geared to the carrier wheel of the differential gear, the shaft of which was connected by chains to the rear wheels. The boiler was a Serpollet instantaneous generator.

The Serpollet System

The boiler used by M. le Blant was the invention of M. Serpollet; its characteristic features were that steam was produced just in proportion to the requirements by injecting water into heated tubes having very narrow passages of C section. Although M. Serpollet did not himself enter a vehicle for the Paris-Rouen contest, he had been at work on steam carriages for some years. In 1888 he built a steam tricycle fitted with his special boiler, and in 1889 he launched out upon more ambitious lines and constructed a carriage to seat seven. This vehicle was mounted on three wheels of which the two in the rear were driven by chains from the shaft of a two-cylinder horizontal engine; the boiler was placed in the rear and between two coke bunkers; fuel was carried sufficient for travelling forty miles, and water for about half that distance; the weight in working order was about one and a quarter tons. In this carriage M. Serpollet recounts that he travelled, with passengers and luggage bringing up the total weight to two tons, a distance of 144 miles, from Paris to Douai, at a cost of eleven francs seventy-five

centimes for coke. Upon good roads a mean speed of seventeen miles per hour was maintained over distances of five miles. Allowing for gradients, this involved a maximum speed of twenty-five miles per hour. M. Serpollet thought this was too high a speed for ordinary roads and not to be recommended.

"Vitesse vertigineuse sur une route et que nous ne conseillons à personne: une absence de surveillance dans la direction, et une catastrophe pourrait se produire." This would no doubt be the case with this particular vehicle, which, judging from the drawing which accompanies the letter[1] of M. Serpollet, would be decidedly unsafe at high speeds. Improved cars were soon produced, however, and two of them ran in the Paris-Bordeaux race of 1895. They were unsuccessful on that occasion, but M. Serpollet has since then driven his cars at speeds far in excess of twenty-five miles per hour.



SERPOLLET STEAM CARRIAGE, 1895.

The Paris-Bordeaux Competition, 1895

Soon after *Le Petit Journal* contest, upon the initiative of the Comte de Dion, who has done so much to help forward the progress of the motor car, a committee was formed to organise another meeting in the following year. The committee decided to make the competition a race, pure and simple, and that the course should be from Paris to Bordeaux and back. Although the award was to be

[1] *La Revue des Inventions Nouvelles*, 5th March, 1895.

based upon speed alone, it is obvious that this involved safety, freedom from breakdown, and ease of management; but on the other hand it took no cognisance of cost of running. There were forty-six entries, but only twenty-two vehicles, including four velocipedes and one electrical carriage, met at the starting-place at Versailles; of these one-half broke down and failed to accomplish the outward journey,[1] and but nine completed the return journey to Paris. It was confidently expected by the partisans of the steam car that a race under the new conditions would show the pre-eminence of steam, but again the petrol motor demonstrated its fitness for the task; of the twenty-two starters, six were steam cars, and fifteen petrol; of the nine that completed the course, eight were petrol carriages and one steam, and again the firms of Panhard & Levassor and Peugeot divided the honours. The car to arrive home first was one of Panhard & Levassor's. The distance was about 740 miles, which was covered in the space of forty-eight and three-quarter hours, giving an average speed of about fifteen miles per hour. This carriage sustained no accident, required not the slightest repair on the road, and it stopped at Bordeaux for eight minutes only; it was driven throughout the run by M. Levassor himself, but the course adopted with most of the other cars was to provide relays of drivers.

Naturally this result attracted a great deal of attention at the time, and one cannot but think that to produce at that period a vehicle and motor that could run continuously for two days and two nights at a speed of fifteen miles per hour was a remarkable achievement. This carriage of Panhard & Levassor's, however, was followed closely by three vehicles by the Peugeot firm, to whom the first prize was awarded, it having been one of the conditions of the race that the first prize could be taken only by a carriage carrying four persons, whereas this carried

[1] Twelve vehicles really completed the outward journey within the time limit, but one of these was disqualified.

two only and so was eligible but for the second prize. After the Peugeots came a carriage by Roger, then another Panhard & Levassor, one of those which had been used in the preceding year for the run from Paris to Rouen, and driven by an amateur. This was followed by another car by the same makers of improved design, like the first, but adapted to carry five passengers; then came another Roger, and finally the Bollée steam omnibus. This was an old vehicle; it had been built in 1880, and its construction is described in Chapter VIII., so it will be sufficient here to state that in travelling order it weighed nearly five tons and that it carried water enough for a journey of twenty-five miles and fuel for about ninety miles. It carried eight persons, including M. Amédée Bollée and some of his workmen, together with a good supply of tools and duplicate parts, by the aid of which a variety of repairs could be effected on the road, one of the conditions of the race being that all breakages should be made good without external aid, either as to men or materials. The stringency of this regulation accounts for a great number of failures to complete the run. Thus one of the De Dion steam vehicles made the journey from Versailles to Blois at the rate of between seventeen and eighteen miles per hour, but after leaving that town sustained a breakage which it was impossible to repair with the means carried on the car. Similarly one of the Panhard cars, which was doing well, ran over a dog and, coming down with a jerk, broke one of its rear wheels. Among the unsuccessful cars, that is to say, those that failed to make the complete run within the time limit of one hundred hours, in addition to the De Dion cars, were the Serpollet steam cars, the Rossel and Michelin petrol cars, the latter fitted with pneumatic tyres, the Duncan and Superbie (Hildebrand & Wolfmüller) bicycle which, in spite of a stop of an hour to repair damages caused by a fire and of time lost by going astray, made a very fair show on the outward journey, and the electrical carriage of M. Jeantaud. Other vehicles shown at the

exhibition held in connection with the race, but not run, were the petrol cycles of De Dion and Bouton, and the petrol carriage of M. Delahaye of Tours. This vehicle was not ready in time for the race; in general arrangement it was similar to the Roger carriages and it was propelled by a two-cylinder engine of about five horse power; it had electrical ignition, and the transmission was effected by belt gearing adapted to give two speeds. The steadiness of running and the absence of vibration in this vehicle attracted considerable attention. The carriage work was also of a superior order, but in this respect there was a general improvement as compared with the cars of the preceding year.

The Paris-Bordeaux race has been succeeded by a series of other competitions, in the course of which engine power and speed have been increased immensely.

The Spread of the Movement to England

Naturally the course of events in France was followed with some degree of interest on this side of the Channel, and the contests of 1894 and 1895 were dealt with more or less fully in our journals. A four horse-power Panhard & Levassor car was brought over to England in June 1895 by the Honourable Evelyn Ellis, and, a little later in the same year, Sir David Salomons brought over a Peugeot car. These cars, together with a De Dion-Bouton steam tractor and a petrol tricycle by the same makers, were shown at work at Tunbridge Wells in October of the same year. This little exhibition had been organised by Sir David Salomons with the object of demonstrating to the British public the practicability of the motor vehicle; it was very largely attended by engineers and others from all parts of the country. Generally speaking, it may be said that the opinion of the engineering visitors was to the effect that the petrol cars appeared to afford some

basis upon which a successful car might be built up, but that a great deal of work was still required in order to produce a vehicle which should meet the ideas of the public in this country.

The praiseworthy efforts of Sir David Salomons, followed by papers read at various scientific and technical societies and articles in the public press, succeeded in arousing the attention of the public, and it became possible to press for a revision of the law relating to the motor car. For although cars were running in this country, they were doing so in contravention of the law, and the drivers were liable to prosecution at any time. In fact at this period the motor car and the motor bicycle were on precisely the same footing as the traction engine in respect to legal restrictions, and, in a few words, their maximum speed was limited to four miles an hour, and each had to be preceded by a man on foot carrying a red danger flag. Of course a motor car could be used under these conditions, but it would be, to say the least, ludicrous in the extreme to so use it. The various Acts of Parliament on the subject had no doubt been framed with reference to traction engines and the like; the passenger vehicle had not been in evidence at the time, and there was no one sufficiently interested to think of safeguarding its prospects in the future, even if it had been thought that the Acts applied to it.

Mr Shaw Lefevre without much delay brought a Bill to amend the law into the House of Commons. Consequent, however, upon the defeat of the Ministry and the change of government, the matter dropped until the following year, when another Bill was introduced. This in due course became law, and November 14, 1896, the date upon which the Light Locomotives Act came into operation, is a red-letter day in the annals of motoring in England. It was celebrated by a procession of motor vehicles in London, and by a run to Brighton in which about twenty cars appeared.

In the meantime interest in the matter had been growing. An International Horseless Carriage Exhibition had been held at the Imperial Institute, at which several French petrol and steam cars and velocipedes were shown, and later in the same year a large collection was on view at the Crystal Palace.

The movement had already its special organs in the press. M. Raoul Vuillemont had established *Le Locomotion Automobile* in 1894, and in November 1895 Mr Sturmey brought out *The Autocar*, and towards the end of 1896 it was represented in addition by *The Automotor Journal*, *The Horseless Age* (New York), *The Motor Cycle* (Chicago), and *L'Automobile Illustrée* (Brussels).

In England, however, the motor-car industry was slow in making a start, but in America, engineers, untrammelled by legal restraints, had been able to proceed with vigour, and towards the end of 1895 it was stated that as many as 300 cars were in course of construction in the United States. In that year the Chicago *Times-Herald* organised a motor vehicle competition, and in England *The Engineer* did the same. The first petrol carriage built in this country was made by Mr J. H. Knight of Farnham, and was at work in July 1895. It was a small three-wheel vehicle to seat two, and weighed with fuel and water about five and a quarter hundredweights; it was propelled by an engine of about one horse-power. Mr Knight states that it ran about 150 miles on the public roads, until the Surrey County Council intervened.

The Daimler Motor Company was formed in February 1896, and in March 1897 they had completed their first carriage (other than experimental productions). Towards the end of 1897 the London Electrical Cab Company placed a number of electric cabs on the streets of London, but they did not prove sufficiently successful to ensure the continuance of the undertaking at that time.

CHAPTER XI

THE PETROL MOTOR

Petrol

THE use of crude pretroleum for medicinal purposes and even for illuminating is of great antiquity, and is referred to by Herodotus, Pliny, and many others of the earlier writers.

It occurs in almost every part of the globe, but the bulk of the illuminating oils and of the "light" or volatile oils or spirits used for motor cars is obtained from the United States, whose crude oil gives a larger yield of the more volatile oils than any other. The following brief description of the industry will therefore be confined to that of the United States.

Although petroleum has so long been known and used, the petroleum industry as a properly carried on commercial process is comparatively new, especially as regards the products which are of importance to the motor driver. So varied, indeed, are the processes of distillation and treatment through which the crude oil is passed before it reaches the consumer, that the petroleum industry may almost be described as a process of manufacture, although the aim of the distiller is to separate the natural products as far as possible into the different constituents which, in admixture, form the crude oil, without decomposing them or altering their composition.

In the United States the oil occurs in the interstices of sandstones in the great oilfields of Pennsylvania and of dolomitic limestone in the oilfields of Ohio and Indiana,

in association with natural gas which may be regarded as gaseous petroleum, for petroleum includes the whole gamut of products from the solid asphalt, which is used to pave our streets, to the natural permanent gas so largely used in the States for heating and lighting purposes.

Whatever may be the origin of petroleum, the principal sources from which it is obtained appear to be merely reservoirs in which it has accumulated. These reservoirs are mainly deep-seated porous strata which have been but little disturbed or metamorphosed, and which are covered by clay, slate, shale, or other impervious strata, which prevent escape of gas or liquid under the heavy pressure usually existing from the accumulation of gas or from other causes.

Although petroleum has been so long known in the States, its value and the enormous supplies which existed were so little realised that, until the early sixties, both shale and coal were distilled at about sixty works under royalty, from Young's Paraffin Company, so well known as distillers of Scotch shale, for the production of oils and spirits similar to those from petroleum.

It was not indeed until the middle of 1859 that the first well actually sunk for petroleum—the celebrated "Drake" well at Oil Creek in Titusville, Pennsylvania—gave birth to the petroleum industry as it now stands.

Crude petroleum consists essentially of a mixture of various liquid compounds of carbon and hydrogen. That of the United States consists of the "paraffin" group of hydrocarbons, while that of Russia, although for most practical purposes scarcely distinguishable from that of the States, belongs to the "aromatic" group known as "naphthenes."

It varies in density from about 0·77 to about 1·02, and in consistency and colour from a highly mobile amber yellow to a black treacly liquid. The presence of sulphur and other impurities, and the fact that it consists of an enormous number of different hydrocarbons which, although belonging to the

same family, are of entirely different character as regards density, volatility, etc., renders it necessary to subject the oil to a complicated process of purification before it can be utilised, and the increasing use of the lighter distillates for motors has led to special refinements in the separation of these lighter products. This separation, indeed, is now carried so far that probably a dozen different light products are separated where three or four sufficed four years ago.

A few of the heavy crude oils are filtered or clarified through animal charcoal and sold for lubricant as "natural oils"; others are exposed to the air or gently heated *in vacuo* or otherwise to expel the bulk of their lighter constituents and are then sold as "reduced oils," but practically the whole of the crude oil, both in the States and elsewhere, is subjected to lengthy processes of distillation and chemical treatment before sale. Various types of still are in use, with condensers arranged to deliver the various distillates into their proper reservoirs.

During the distillation the crude oil is separated roughly into three products, the yield in Pennsylvania being roughly:—naphtha, eight to ten per cent.; refined oils, seventy to seventy-eight per cent.; and residuum, five to nine per cent.

A certain amount of decomposition occurs during the distillation, so that the products are not identical with those actually present in the crude oil, and every means is adopted to reduce such decomposition to a minimum excepting during one stage of the distillation, when it is encouraged by what is known as the "cracking process," by allowing the "intermediate" oils, which are slightly less volatile than the kerosene or lamp oil, to return to the still, where they are partly decomposed with the production of a higher yield of kerosene, the most saleable of all the distillation products.

The "residuum" mentioned above is separated by distillation and chemical treatment into lubricating oil, paraffin wax, vaseline, etc.; the refined oils are similarly

"fractioned" into intermediate oil and kerosene, and the naphtha into a large number of separate products whose names are legion and whose composition varies so much that the name is frequently misleading. Products of the same name purchased at different times or at different places are indeed very commonly of different composition.

The distillates as obtained cannot be satisfactorily used on account of their unpleasant smell and colour, and because they rapidly choke up the nozzles of petroleum burners or the wicks of lamps. They are therefore first subjected to a treatment with sulphuric acid, which removes the bulk of the objectionable impurities and then to a wash with soda lye, which neutralises the free acid and further purifies the oil. A final washing with water completes the treatment which, simple though it sounds, is one of the most important of the industries of the States, and is carried on in many cases in works which are entirely independent of the distilleries.

In *Petroleum and Its Products*, by Redwood & Holloway (1896), it is stated that crude naphtha is commonly separated into four products, known as gasoline and C., B. and A. naphthas, gasoline being itself sometimes divided into three products, termed cymogene, rhigoline and "gasoline." By the distillation of ordinary crude gasoline and condensation of the first distillate with a freezing mixture of ice and salt, Merrill first obtained rhigoline, having a density of 94° Beaumé and a boiling point of 65° F. Cymogene, which is similarly prepared, is said by Sadtler to boil at 32° F., and to have a density of 110° B.

In some instances the following are manufactured:—

	Density Beaumé.	Specific Gravity.	Used for
Rhigoline or Cymogene.	90°	0·636	Local anæsthetic.
Gasoline . . .	88-86°	0·642-0·628	Air-gas machines.
Boulevard Gas Fluid .	76°	0·682	Street naphtha lamps.
Prime City Naphtha, (Benzoline) .	73-68°	0·692-0·709	Sponge lamps.
Benzine. . . .	62°	0·731	Oilcloth and varnish making.

The percentage of these products varies, but as a rule amounts to about twenty-five per cent. of the first three (rhigoline accounting for about a tenth of a per cent. and gasoline for from one to three per cent.), rather over twenty-five per cent. of the fourth, and about forty per cent. of the fifth, all percentages referring to the amount yielded by the crude naphtha.

Other refiners separate the following products:—

		Density Beaumé.	Specific Gravity.
Petroleum Ether	1. Cymogene . . .	108°	0·590
	2. Rhigoline . . .	94-92°	0·625-0·631
	3. Gasoline	95-80°	0·635-0·668
Petroleum Spirit	4. C. Naphtha (Benzine Naphtha) . .	76-70°	0·682-0·702
	5. B. Naphtha . . .	66-65°	0·716-0·720
	6. A. Naphtha (Benzine) .	59-58°	0·743-0·747

According to A. H. Allen, cymogene consists mainly of butane, rhigoline of pentane and isopentane, and gasoline of hexane and isohexane.

The ordinary American "petroleum ether" has, according to Veith, a specific gravity of 0·63 to 0·65. Certain oils obtained during the compression of "oil gas," and

known technically as "hydrocarbon," are also sold as petroleum ether according to Evers. The "benzin" of the United States pharmacopœia is the portion of the distillate from American petroleum boiling between 50° and 60° C. (122° F. and 140° F.), and having a density of 0·670 to 0·675. The "petroleum benzin" of the German pharmacopœia consists of the colourless, non-fluorescent portion of petroleum distillate having a density of 0·640 to 0·670 and distilling between 55° and 75° C. (131° F. and 167° F.). The New York Produce Exchange requires that petroleum naphtha shall be "water-white and sweet" and shall have a density of 68° to 70° B. (specific gravity 0·707 to 0·690).

The name "ligroin" is sometimes given to petroleum spirit having a density of 0·685 to 0·690.

Such terms as "petroline," "essence," etc., are arbitrary names given on the Continent to light spirits used for propelling motor cars, but are not confined to special distillates, while, of course, the names "benzol" and "benzene," though occasionally erroneously applied to petroleum spirit, should never be used except for coal-tar benzene, which is not used alone as a motor-car spirit, although it is said to be used for that purpose in conjunction with alcohol on the Continent. Alcohol alone is also used there for the purpose, but of course has no connection with petroleum spirit.

The increasing use of motor spirits, where purity and constancy in composition is of primary importance, has led to considerable increase in the care with which these lighter distillates from petroleum are prepared, and to the introduction, under special names, of products whose makers claim that they possess the above advantages. Such, for instance, are "Pratts' motor spirit," introduced by the Anglo-American Oil Co., and the "Petrol" of Messrs Carless, Capel & Leonard. Both have a density of 0·680, and consist mainly of the hydrocarbon known as "heptane." Many other of the light naphthas, such as the

benzine, benzoline, gasoline, etc., previously referred to, may also be used, provided they are obtained from a reliable source.

An important point in the use of all these spirits is the fact that any spirit which consists of a mixture of several constituents vaporising at different temperatures, is liable to lose a portion of its lighter constituents, so that what remains in a tank or reservoir becomes inefficient. The desirability of frequently taking the density of the spirit, not forgetting to make the proper allowance for temperature, if this be not 60° F. is therefore manifest. For this reason it is important that no constituent of a motor spirit should vary greatly from a density of 0·680. A spirit of this density could of course be prepared by mixing a heavy with a very light spirit with disastrous consequences to the user.

The determination of the "flash point," of motor spirit is never made because all such spirit comes below the legal point of 73° F. (Abel test) for a safe petroleum "oil" and burns at the ordinary temperature, or forms an explosive mixture when sprayed into or otherwise admixed with the air. For ordinary kerosene or lamp oil, however, the flash-point test (which must not fall below 73° F.) is of great importance, as are also of course the density and the freedom from water and sediment.

The specific gravity of American kerosene varies from 0·795 to 0·810, while that of Russia is about 0·822. The New York Produce Exchange provides that refined kerosene shall have a flash point of 70° F. (Abel test) or higher, and a specific gravity of not less than 0·810 (44° B.). On fractional distillation it should mainly boil away between 150° C. (302° F.) and 300° C. (572° F.), whereas all petroleum "spirit" is evaporated by a temperature of less than 150° C.

The composition of kerosene varies largely, but it consists of a mixture of the less volatile members of the same group of hydrocarbons as make up petroleum spirit,

etc. The different hydrocarbons which constitute it are, however, so numerous that it would be useless to attempt to name them.

The term "solar oil" is applied to a Russian oil intermediate between kerosene and lubricating oil. It has a density of about 0·860 and a flashing point of about 220° F. (Abel test), but is not of present interest in connection with motors.

ALCOHOL

The problem of substituting alcohol for petrol as a fuel for motor cars has received considerable attention in France and Germany during the past year or so. The question is purely economic in its origin, it being considered desirable to foster home agriculture as far as possible and in preference to importing foreign commodities.

It has been fully demonstrated that alcohol can be so substituted, and that as far as its action in the engine is concerned no particular difficulty attends its use. Alcohol, however, does not vaporise so readily as petrol, so some heating arrangement has to be applied to the vaporiser, which also, in view of the increased consumption in the case of alcohol, requires to have a larger orifice for the jet; in other respects the same engine may be used indifferently for petrol or for alcohol, but in order to obtain the best results with alcohol, motors of somewhat different proportions appear to be advisable.

As indicated above, for the same power, the consumption of alcohol is greater than that of petrol; it is difficult to say exactly to what extent, perhaps fifty to eighty per cent. is about the mark when alcohol is used alone. This increased consumption necessitates more frequent stops to replenish the supply, or else increased tank capacity, and thus more dead weight to be carried, and will probably be felt as a serious obstacle to the general use of alcohol, at least for touring purposes. At present petrol appears to be the

cheaper fuel, but in Germany, where alcohol is very cheap, some experimental researches bring out the cost with alcohol as only six per cent. higher than with petrol, and no doubt with specially-designed engines a better result would be obtained, while an increase in the consumption would probably have the effect of reducing the price of the alcohol. In France alcohol is considerably higher in price, but this is mainly due to the government duty, which could be considerably reduced.

Alcohol intended for industrial purposes is liable to a smaller duty than that for beverages, etc., and is denatured by the addition of some substance which will render it unfit for drinking—malachite green and heavy benzine, a coal-tar distillate, are used in France for this purpose. These substances are objectionable in the engines. In practice a mixture of equal parts of petrol and alcohol is used in preference to alcohol alone, and it has been suggested that petrol should be used for denaturing, but petrol could probably be separated by distillation so that it would not serve the purpose.

The efforts made in France to assist the agricultural interest by increasing the consumption of alcohol, which is prepared from beetroots, have had the unforeseen effect of giving rise to the artificial production of that substance from acetylene.

The Petrol Motor

The petrol motor, like the steam engine, belongs to the class of prime movers known as heat engines, but whereas in the steam engine the heat is produced by the combustion of fuel, whether solid, liquid or gaseous, outside the working cylinder, that is to say under the boiler, in the petrol motor the combustion takes place in the cylinder itself; hence the term "internal-combustion engine." The operation of the motor is due directly to the expansion of a mixture of a hydrocarbon vapour and air when ignited; the combustion

of the vapour gives rise to great heat under which the resulting gases increase in pressure and volume; the action is very rapid, so much so that it may be regarded as an explosion, and these motors are sometimes called explosion engines.

The combustion takes place in a cylinder fitted with a movable piston. In essentials the cylinder is simply a round box of uniform internal diameter closed at one end and provided with two openings, one for admitting the charge of mixed vapour and air, sometimes called "mixture," and the other for allowing the escape of the burnt gas. These openings are provided with doors or valves, termed respectively the "inlet" or "induction" valve, and the "exhaust" valve. The piston used in these engines is a similar round box, adapted to work freely to and fro in the cylinder; to prevent the escape of gas around it a number of annular grooves are cut on the surface of the piston to receive iron rings which, having a slight spring, press outwards against the cylinder. The piston is linked by the connecting rod to the crank on the fly-wheel shaft.

The cycle of operations is precisely the same as that of the ordinary gas engine; it is the four-stroke, Otto, or Beau de Rochas cycle. Other cycles have been devised, but they do not call for consideration here. Briefly the sequence of operations, taking for convenience of description the vertical arrangement of engine, is the following. Starting with the piston in its highest position in the cylinder, the expulsion of the products of combustion of a preceding cycle having just been completed, the onward movement of the crank pulls down the piston, behind which a partial vacuum is formed; the pressure of the atmosphere thereupon forces open the inlet valve against the resistance of its spring, and the mixed vapour and air rush into the cylinder. This is the "suction" or "induction" stroke of the engine, and when the piston arrives at its lowest position the cylinder is charged with the combustible mixture. As the piston, under the influence of the crank, begins to

move upwards the pressure in the cylinder rises, and the inlet valve is closed by its spring; the continued movement of the piston compresses the charge, until at the end of the stroke—the "compression" stroke—the space above the piston, known as the combustion chamber, is charged to a pressure of from eighty to one hundred pounds. The compressed charge is ignited, the vapour and the oxygen of the air enter into combination, and the sudden expansion drives down the piston. This is the effective or working stroke. The pressure upon the piston is transmitted by the connecting rod to the crank and causes the rotation of the shaft. The crank also serves to limit the to-and-fro movement of the piston in the cylinder and, when the working stroke is completed, being carried onwards by the fly wheel, it pushes the piston upwards, driving the burnt gas before it, and expelling it through the exhaust opening, the valve of which has been opened by mechanism for this purpose. This is the "exhaust" stroke, and completes the cycle, which is shown diagrammatically in the accompanying illustration. It will be seen that the sequence is, suction, compression, working, exhaust, and that these four strokes correspond to two revolutions of the fly wheel, and the function of this part is to store up the power produced at the working stroke, to return to the engine that part required for the production of the exhaust, suction, and compression strokes, and to distribute the balance as uniformly as possible to the machine or part to be driven.

It is of vital importance in the working of the engine that there shall be no leakage round the piston or through the valves when closed. If leakage occurs, it is clear that part of the charge drawn in on the suction stroke will be lost on the compression stroke, with the result that there will be a considerable falling off in the power developed. High compression has also the effect of increasing the efficiency of the engine, that is to say the power developed by a given consumption of petrol.

The liquid petrol is vaporised and mixed with air, or, to

put it in another way, the air is carburised or charged with hydrocarbon vapour before its admission into the cylinder, by means of the *carburetter*. There are various constructions of this apparatus in use, and some typical forms will be considered later on.

The explosion or firing of the charge when compressed in the cylinder may be effected either by contact with an incandescent tube projecting through the cylinder wall and heated by a lamp placed outside, or by the electric spark. The spark may be produced by means of a primary or a

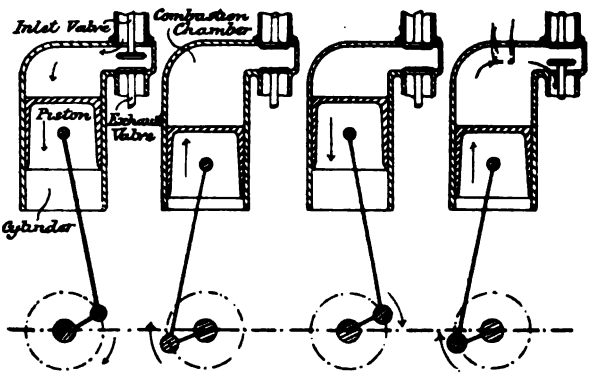
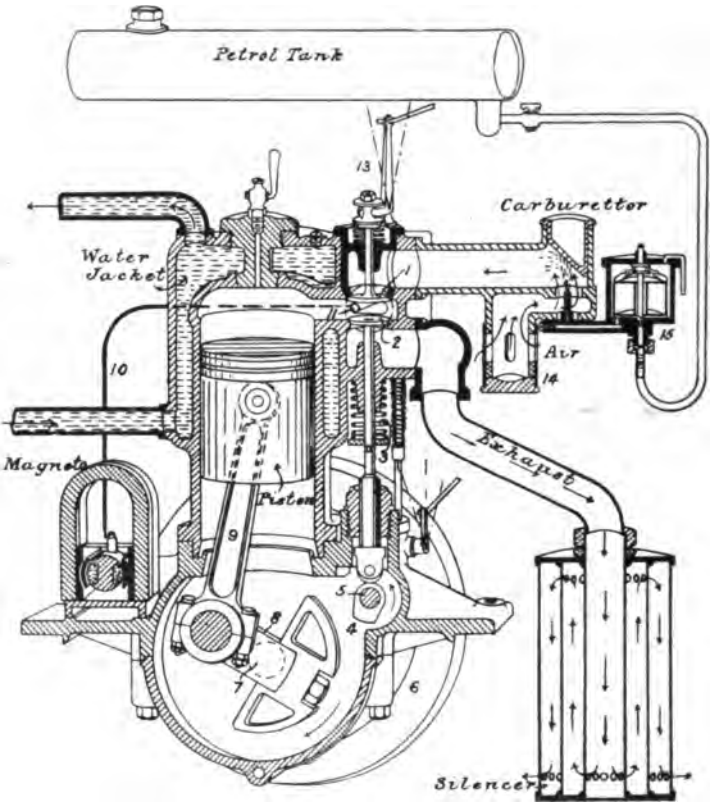


DIAGRAM OF THE FOUR-STROKE OR OTTO CYCLE.

secondary battery and induction coil, or by means of a magneto-electric machine driven by the engine itself. The construction and action of these parts will be found discussed under the heading *Ignition*.

The inlet or induction valve is in some cases operated mechanically, but usually it is, as stated above, opened by atmospheric pressure and closed by a spring. The exhaust valve is likewise closed by a spring, but it is opened by mechanism worked by the fly-wheel shaft; for this purpose the valve, which, like the inlet valve, consists of a disc adapted to cover a round opening, is provided with a stem; this projects downwards into contact with the top of a

rod, the lower end of which rests upon a rotating cam, in the form of a disc, having a projection on one side. As in



1. Inlet Valve.
2. Exhaust Valve.
3. Spring for Valve.
4. Cam.
5. Cam Shaft.
6. Fly Wheel.
7. Crank Shaft.
8. Crank.
9. Connecting Rod.
10. Insulated Wire.
11. Ignition Pin.
12. Lever for regulating Lift of Inlet Valve.
13. Cap for regulating Air Supply.
14. Float-feed Chamber.

SCHEME OF PETROL ENGINE, FITTED WITH SIMMS-BOSCH MAGNETO-IGNITION AND FLOAT-FEED SPRAY CARBURETTER.

the rotation of the cam the projection moves under it, the rod is pushed upwards and lifts the valve from the opening,

and while the projection remains under the rod the valve remains open. As the projection moves clear of it the rod is free to descend into contact with the body of the disc and the valve is drawn down by its spring. When the projection next comes round the action is repeated, so that the valve is opened once for each revolution of the cam. But as there is but one exhaust stroke for every two revolutions of the fly wheel, it is clear that the cam cannot be placed on the engine shaft; it is therefore mounted on a special shaft driven from the engine shaft by toothed wheels proportioned to run it at half the speed. This shaft is sometimes called the "half-speed shaft." In order to avoid back pressure, the cam is arranged to open the valve before the end of the working stroke; the small loss thereby occasioned in actual driving force is more than compensated for by the diminished resistance in the exhaust stroke. The valve closes at the end of the exhaust stroke.

It is clear that the engine can commence working only when there is a charge of the compressed mixture in the cylinder ready to ignite; it is therefore necessary in order to start the engine to give the shaft a few turns by hand, and for this pupose a handle is provided to fit over the end of the shaft or of a spindle geared thereto. When the engine gains speed, the handle is pushed off automatically.

The compression stroke takes some power, and in order to ease the labour of starting, it is usual to provide for reducing the extent of the compression either by providing a relief cock or by keeping the exhaust valve lifted by means of a valve lifter actuated by hand or mechanically.

Carburetters and Vaporisers

The reason for the use of petrol or petroleum spirit in the motor car in preference to the safer and more economical kerosene or lamp petroleum is to be found mainly in the superior simplicity of the carburising apparatus required

for the more volatile liquid. Petrol has other advantages, for instance its waste gases do not smell so disagreeably as those of kerosene, but the facility with which it is converted into vapour is its chief merit, and is undoubtedly the cause of the preference given to petrol.

At the ordinary temperature of the atmosphere petrol will be vaporised merely by contact with the air, and carburetters known as "surface" carburetters are in use which act in this way. But it must be noted that the rate at which the vapour is formed depends upon the temperature, so that upon a cold day it might be too low to supply the requirements of the engine, and beyond this it is a matter of common experience that the process of evaporation causes a fall in temperature. A drop of eau-de-Cologne or other spirit poured on the hand causes a sensation of coolness as it evaporates. It is therefore usual to provide some means for supplying heat to the liquid. The carburetter should be arranged to expose a large surface of liquid to the action of the air. This end may be attained by the use of wicks hung in the air current and kept saturated with petrol. An example of such a carburetter is to be found in the Lanchester carriage. In another type the air supply is caused to bubble up through the liquid, which should be maintained at a constant level to insure uniform results. The old Daimler carburetter, and that in use on the Delahaye cars are examples of this class. Other inventors have sought to attain the same end by splashing the liquid about by means of rotating paddles.

The De Dion-Bouton carburetter for cycles, etc., may be taken as an example of a surface carburetter which has given good results. It consists of a chamber which is charged about half full with petrol, and is fitted with a vertical telescopic pipe through which air is drawn in; the pipe terminates near the surface of the petrol under a horizontal partition, between which and the surface of the liquid the air flows towards the sides of the chamber, and, charged with vapour, escapes to the upper part of the

chamber, where the mixture is supposed to become more homogeneous. At the top of the chamber is a double valve or twin tap; one valve has an opening to the external air and another to the carburetter chamber. By turning the valve, one opening may be closed and the other opened or *vice versâ*, or they may be opened in any required relative proportions. By this means any desired proportion of external air may be admitted and mixed with the carburised air. In brief, this valve controls the quality of the mixture; the other valve controls the quantity allowed to pass through the inlet pipe to the engine. The petrol in the chamber may be warmed by means of a pipe passing through it, along which a part of the engine exhaust gases may be discharged.

C. Carburetter Chamber.
J. Air Inlet Pipe.
L. Partition under which the air is delivered.
F. Float resting on surface of petrol; its stem projects at the top of the pipe J to indicate the level of the petrol.
A. Pipe connected at H to a branch from the Exhaust Pipe.
G. Quantity Lever, regulating supply to engine.
G[1]. Quality Lever, regulating proportions of mixture.
E. Supply Pipe to engine.
V. Wire Gauze to prevent passage of flame from engine to carburetter.

THE DE DION-BOUTON SURFACE CARBURETTER.

But the surface carburetter, although simple and free from liability to mechanical derangement takes up a comparatively large space and is susceptible to atmospheric changes. Further, it exercises a selective action upon the mixture of hydrocarbons which go to form petrol, for it is clear that with mere surface action the more volatile compounds are carried off first; this proceeds until a

stage is reached at which the liquid remaining in the tank refuses to vaporise, and has to be replaced by a fresh supply. The speed of the engine also has an effect upon the carburisation; at a high speed the air is drawn through the apparatus very rapidly, and is not in contact with the liquid for a sufficiently long time to take up a large amount of the vapour.

These disadvantages are leading to the general adoption of some form of spray apparatus, in which the liquid is reduced to the state of a fine mist or spray before it is mixed with the air. The air in this case is not free to select the more volatile compounds from the mass of the liquid, and the fine spray, even if it is not immediately vaporised, is carried along with the air to the cylinder, the heat of which at once converts it into vapour. More uniform carburisation is attained, but the spray carburetter is a more delicate piece of apparatus, and the fine nozzle necessary for the delivery of the petrol is liable to become blocked.

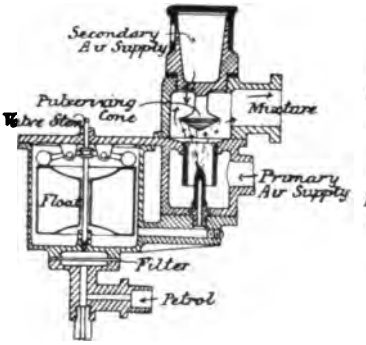
In general the supply of petrol to a spray apparatus is controlled by a float and valve, in much the same way as the water supply to a domestic cistern. The rise of a hollow metal float is caused to depress a small valve, which fits in the supply opening in the bottom of the float chamber, and to which the pipe from the petrol tank is led. Usually the opening is directly below the centre of the float, and the stem of the valve passes up through the float and emerges through an opening in the top of the chamber, so that it may be pressed down by the finger to test the free working of the parts. In some cases provision is made for keeping the valve pressed down, to arrest the flow of petrol into the apparatus, in the form of a pivoted spring blade, which may be turned over the head of the valve stem. The float acts upon the valve by means of a pair of small levers; these are pivoted in projections formed on the top of the chamber, and bear at their outer ends upon the float, while their inner ends

engage with a grooved collar on the spindle. The upward or downward movement of the float thus produces a reduced movement in the opposite direction of the valve. At the side of the float chamber is the carburetter chamber itself, provided with a vertical jet pipe or nozzle, the lower end of which opens into the float chamber. The liquid thus stands at the same level in the nozzle as it does in the float chamber, and this level should be a little below the top of the nozzle. The carburetter chamber is provided with an adjustable inlet for atmospheric air, and with an opening placed in communication with the inlet opening on the engine cylinder. Upon the suction stroke the pressure therein is reduced, the petrol jets out from the nozzle, and the air rushes in to mix with and carry on the spray or vapour to the cylinder. The size of the nozzle has to be carefully adjusted in the first instance for the supply of the correct amount of petrol; it is very small, and hence is liable to be become blocked by sediment or solid particles carried along with the petrol, and this is one of the main sources of difficulty with the spray carburetter. It is usual to allow the jet to impinge upon an inclined surface or a cone to assist in atomising or pulverising it, and the air is frequently supplied in two stages, the primary supply entering with the petrol and becoming highly charged, and the secondary supply, adjustable according to requirements, serving to dilute this rich mixture to suit the work to be done by the engine. The Daimler-Phœnix shown on the next page is an example of such a carburetter, the secondary air supply being regulated by means of a cap which may be turned to cause openings formed in it to register more or less with openings in the carburetter chamber. In the Abeille carburetter, also shown in the drawing, the secondary air supply is introduced through perforations in the pulverising cone, and the float, instead of being placed directly over the valve, is placed at the side of it.

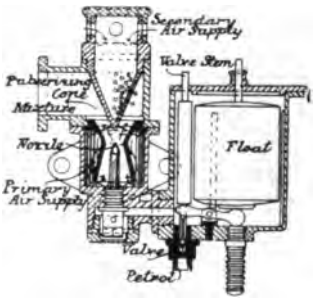
The carburetter is placed in close proximity to the

engine, in order that it may be kept warm by the heat radiated from the cylinder. In addition to this, to ensure the working of the apparatus under unfavourable conditions, the carburetter may be enclosed in a jacket heated by the waste gases, or by the water which has been heated by circulation in the cylinder jackets.

This feature is to be met with in the Longuemare carburetters. In the float-feed carburetter of this maker, shown in the drawing, the vertical jet nozzle is enclosed in a small hood having radial perforations, through which, on



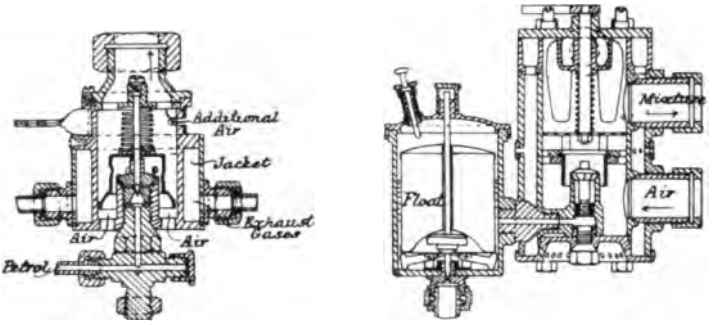
THE DAIMLER-PHŒNIX CARBURETTER.



THE ABEILLE CARBURETTER.

the suction stroke of the engine, the petrol issues into a surrounding cylinder. This cylinder is suspended in a cylindrical chamber and serves to divide into two parts the current of air drawn in through an opening near the bottom, one part passing inside the cylinder, and becoming charged with petrol vapour or spray, and the other outside. The two currents unite in the upper part of the chamber before they reach the outlet for the combustible mixture, and the mixing is assisted by a perforated baffle plate. The openings through which the outer current passes may be adjusted in size by a handle at the top of the chamber. This affords a means for regulating the amount of pure air, and thus of the richness of the mixture. The

chamber is warmed by circulating the exhaust gases through a jacket, and in addition to this, in the form shown in the drawing, radiating wings project downwards into the chamber from a box in its upper end, through which the hot gases are circulated; the mixture is warmed by contact with these wings. This carburetter acts equally well with alcohol, but in this case it is found necessary to warm up the apparatus before starting to work. This is done by applying a torch to the bottom. The heated gas from the torch enters the jacket by a row of holes in the



LONGUEMARE CARBURETTERS.

bottom, which under normal conditions form the escape holes for the jacket gas, and escape through another row of holes opened for the purpose by turning a clip ring. In order to adapt this apparatus for use either with alcohol or with petrol at will, the jet pipe is provided with a valve having a handle below the carburetter chamber; this enables the requisite change in the rate of flow to be effected.

In another type of Longuemare carburetter, also shown in the illustration, the float for regulating the supply of petrol is dispensed with, and a valve which opens automatically on the suction stroke of the engine is used instead. The jet nozzle is fitted with a valve pressed down by a spring and lifted on the suction stroke by the

pressure of the air on a bell to which it is fixed. This bell nearly fills the carburetter chamber, and covers the openings for the admission of air formed in the bottom thereof. The inrush of air pushes up the bell and lifts the valve, the petrol thereupon jets out against the bell and the spray and air escape through perforation into the chamber, which is fitted with an adjustable secondary air supply and has an outlet at the top for connection to the engine.

The Creek Company's carburetter affords another example of a spray apparatus without a float feed. The carburetter chamber is fitted with an air inlet valve which is normally pressed against its seat by a spring; in the seat is formed a small opening for the petrol which is covered by the edge of the valve. Upon the suction stroke the valve is drawn off its seat, uncovering at the same time the air and petrol openings. The chamber is fitted round the exhaust pipe, and is formed with a helical baffle plate or partition.

The petrol tank may be placed at a higher level than the carburetter, so that the petrol flows into the latter by gravity, or it may be placed at a lower level; the pressure of the exhaust gases of the engine is then brought to bear on the surface of the petrol to force it to the carburetter.

IGNITION

The charge, consisting of petrol vapour and air, may be ignited in various ways. Under certain conditions the ignition may occur spontaneously when the compression has reached a certain point, as in the first Daimler engines. It may be produced by the action of spongy platinum, platinum wire, or osmium wire, which have the property of being maintained incandescent in an atmosphere of combustible gas and air. But in practice two systems of ignition prevail, almost to the exclusion of all others. These are the incandescent tube ignition and electric ignition, of which

there are two forms, the high-tension system and the low-tension system.

Tube Ignition.—In this system a tube, usually of platinum, closed at its outer end, is fixed in the wall of the combustion chamber, its outer end projects and is kept red hot by the flame of a bunsen burner, its inner end is open so that the gases in the combustion chamber have access to it; the charge as it is compressed penetrates into the tube, pushing back the burnt gases retained in it, and at a certain stage become ignited. The tube has to be carefully set to produce ignition at the most favourable point, and once set is not adjustable.

The burners are fed with petrol either by gravity or by pressure exerted on the surface of the fluid in a tank. The use of petrol is one of the leading advantages of the tube system. The automobilist has merely to be certain of his supply of one thing, which serves both as the motor fluid and as fuel for the burners; on the other hand the burners are apt to get blown out, and they constitute a source of danger from fire, particularly in the case of the overturn of the car. Still the tube system is very simple and reliable, and it has worked well on the whole; it is nevertheless giving way to some form of electric ignition, which although more complicated has considerable advantages.

High-tension Electric Ignition.—In the high-tension electric system the ignition is effected by sparks jumping across between two terminals or sparking points situated in the combustion chamber, the gap between the two points constituting a break in an electric circuit. In order to jump across such a gap, however small, in an atmosphere of compressed gas, the current requires to be of greater strength than that produced by the means usually available, *i.e.*, primary batteries or accumulators. Use is therefore made of the induction coil, by means of which a current of low-tension electricity in one circuit induces a current of very much greater strength in another. The construction and action of the induction coil are extremely

interesting. It will be sufficient for the present purpose to say that it consists of a core composed of a bundle of soft iron wires, enclosed in a primary or inner winding of insulated copper wire and an outer or secondary winding also of insulated copper wire, and quite distinct from the inner winding. One terminal of the secondary coil is connected by an insulated wire to one of the sparking points. The other is connected to the other point either by a wire or through the framework of the engine. The primary coil has one end connected directly to one terminal of the battery, and the other end to the other terminal through a switch and a contact breaker by which the circuit or path for the flow of electricity may be completed and broken; here again the framework of the machine may form part of the circuit. The mere steady flow of electricity from the battery through the primary coil has no effect upon the secondary, but upon the interruption of this flow, by means of the contact breaker, momentary currents are induced in the secondary of greater strength, depending upon the number of coils.

The contact breaker, the action of which produces the sparks, is worked at the required point in the piston stroke by a rotating part of the engine. In one form it takes the form of a disc, made of some insulating material, fixed on the half-speed or cam shaft, and provided at one part of its periphery with a segment of conducting material to which one wire of the primary circuit is connected; the other wire is led to a spring contact held against the edge of the disc, so that when the conducting segment comes under it the circuit is completed, and current passes through the inner coil.

To insure the ignition of the combustible mixture it is preferred to pass a stream of sparks between the sparking points, and this is effected by fitting a trembler on the induction coil; the trembler consists of a spring blade, mounted near the end of the coil, which normally bears upon a contact to which the wire is led, the end of the coil itself

being connected to the trembler so that normally the circuit is continuous at this point; when the current passes the soft iron core becomes magnetised and attracts a soft iron disc on the trembler blade, which is thus drawn away from the contact, breaking the circuit; the cessation of the flow at once produces a current in the secondary coil, the core loses its magnetism and the trembler springs back against the contact, again completing the circuit, and so on, as long as the conducting segment of the contact breaker is under the spring contact.

In small high-speed engines the trembler is combined with the contact maker on the cam shaft; one wire is connected to an adjustable contact and the other to a spring blade, the free end of which rests upon a cam, whereby for the greater part of the revolution it is kept away from the adjustable contact. The cam is, however, formed with a deep gap, and when this arrives under it, the blade is free to spring inwards against the contact, and under the influence of the spring it is supposed to continue to vibrate, making and breaking contact, until it is again lifted by the cam clear of the contact.

A great advantage of the electric system is that it allows the time of ignition to be varied in reference to the stroke of the piston. This is effected by turning the part which carries the spring contact, or the spring blade as the case may be, round the cam shaft.

The primary batteries employed for ignition purposes are usually dry batteries, as in the De Dion-Bouton cars. Accumulators or secondary batteries are, however, more generally favoured, and several are on the market specially constructed to stand the shock and vibration incidental to the petrol car. In Messrs Peto & Radford's "Armoured" accumulator, for instance, the plates, enclosed in a transparent celluloid cell, consist of light grids, into the compartments of which the paste of lead oxide is pressed, and each plate is placed between two perforated sheets of ebonite or celluloid in a lead cage. By this means the

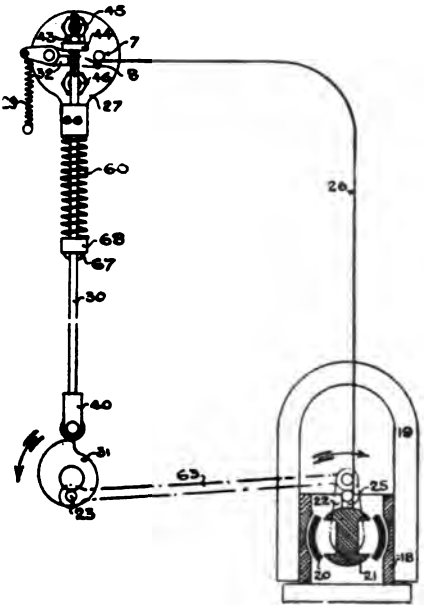
bridging across of the plates is prevented, and should any of the paste become detached, it cannot fall down to the bottom of the cell and cause a short circuit.

In order to lead the high-tension wire into the combustion chamber in such a manner that it shall be perfectly insulated and that there shall be no leakage of gas where it passes through the wall, a sparking plug is employed. This consists of a metal body adapted to be screwed into a hole in the combustion chamber, and fitted with porcelain, mica, glass, or some insulating material which will stand intense heat, through the centre of which the wire is led; the end of the wire terminates in close proximity to a wire or stud formed on the plug itself, the space between forming the spark gap.

Low-tension Electric Ignition.—The Simms-Bosch magneto system comprises three essential parts: the magneto machine, the ignition plug, and the timing gear. The magneto machine is of very simple construction; it consists of two or more permanent horse-shoe magnets standing vertically on a baseplate of bronze; of a soft armature core of H section wound with insulated copper wire, which is connected at one end to a terminal and at the other to the core; and of a soft iron shield interposed between the armature and the pole pieces of the magnets. The shield consists of two segments connected at the ends and provided with pivots, on one of which is an arm by which it receives an oscillatory motion. At a certain period in the oscillation a flow of electricity is set up in the wire of the armature.

The ignition plug is in the form of a disc bolted against an opening in the cylinder; in it are mounted an insulated pin, connected by a wire to the terminal on the armature, and a spindle which, inside the cylinder, bears an interrupter arm. This arm is normally held in contact with the inner end of the insulated pin by means of a light spring acting on another arm secured to the spindle outside the cylinder. In this position an unbroken circuit

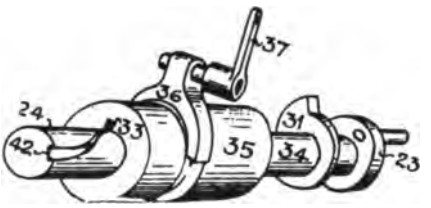
is provided for the electric current from the terminal on the armature to the insulated pin through the interrupter arm and back through the metal of the engine to the other end of the armature. This circuit is broken at the required instant in order to produce a spark in the cylinder by moving the interrupter arm away from the pin. Outside the cylinder is a vertical rod which bears at its lower end upon a revolving cam; normally the arm is kept elevated by the cam, but at a certain point in the revolution a depression in the cam allows it to move downwards, under the influence of a spring, and a projection on its upper end strikes the external arm on the spindle, which is thereby turned and sharply moves the interrupter arm away from the pin. The position and movement of the oscillating sleeve is carefully adjusted to produce the maximum flow of electricity at the moment of breaking the circuit, and to



19. Magnets.
20. Oscillating Shield.
21. Fixed Armature.
22. Arm for Oscillating Shield.
23. Crank for Oscillating Shield.
63. Link for Oscillating Shield.
25. Terminal.
26. Conducting Wire.
27. Ignition Plug.
7. Insulated Pin.
8. Interrupter Arm, inside Cylinder.
29. Spring holding arm in contact with pin.
30. Vertical Sliding Rod.
31. Cam.
44. Tappet or projection on rod.
32. Arm on Spindle.

SIMMS-BOSCH MAGNETO IGNITION.

ensure that this is maintained the ignition cam and the crank by which the sleeve is worked are rigidly secured to the same spindle. For the purpose of regulating the time at which the rupture occurs, or, in other words, timing the ignition, this spindle is made angularly adjustable in relation to the cam shaft of the exhaust valves, by which it is driven, and accordingly also to the engine shaft; to effect this the cam shaft and the spindle are connected by a coupling sleeve provided with internal keys, one to engage a straight groove in the spindle and the other a helical groove in the cam shaft. It will be seen that the sleeve will cause the two parts to rotate together, but that one may be advanced or retarded in relation to the other by moving the sleeve endways, which is done by a forked lever engaging an annular groove on its outer surface. In another arrangement of timing gear, instead of moving the cam, the vertical rod is moved sideways.



23. Crank for working Magneto.
24. Cam Shaft for Valves.
31. Ignition Cam.
34. Spindle.
35. Coupling Sleeve.
36, 37. Levers for moving Sleeve.
33. Key in Sleeve.
42. Helical Groove in Cam Shaft.

SIMMS-BOSCH TIMING GEAR.

The apparatus comes into action directly the motor is started, and is entirely automatic in operation, requiring no accessories in the nature of batteries, coils or tremblers. And as long as the insulation of the conducting wire and pin are maintained perfect it does not appear that any trouble should arise from the electrical system. It is certainly somewhat heavier than the high-tension apparatus, but in the total weight of a car the difference is inconsiderable. The permanent magnets will, in course of time, require to be re-magnetised, and the pivots and joints

will wear and require adjustment and renewal, otherwise there appears to be nothing to get out of order.

Regulating and Governing

There are a large number of systems in use for regulating the power developed by the motor. With one exception they all resolve themselves essentially into means for controlling the consumption of motor fluid. The exception is the system of control by variable timing of the ignition, which is, of course, applicable only in connection with electrical ignition. It has been shown how such variation may be effected. To ensure complete combustion at the commencement of the working stroke which is necessary to the full utilisation of the motor fluid, the spark must be produced at some point before the end of the compression stroke, while if the moment of ignition is later, full combustion does not occur until after the piston has begun its working stroke, with the result that there is a falling off in the power produced. It is clear that this feature may be used for regulating the power given off, but that it does so by throwing away a part of the power available, unless it is used in conjunction with some means of regulating the supply of motor fluid.

The consumption of motor fluid may be controlled in several ways. *The amount of petrol* supplied at each stroke of the engine may be adjusted; the carburetter may be supplied with valves for *regulating* the *quantity* and *quality* of the *mixture* allowed to pass on to the cylinder; a *throttle valve* may be fitted in the inlet pipe to restrict more or less the flow from the carburetter to the cylinder, or the *inlet valves themselves* may be caused to rise to a greater or less extent for the same purpose; the inlet valves may be prevented from rising at all, so that no charge is admitted to the cylinder.

All these are direct ways of controlling the consumption; in addition there are the methods of controlling *through*

the exhaust valve; the exhaust valve may be *kept closed* during the exhaust stroke, so that the exhaust gases are retained in the cylinder and prevent the opening of the inlet valve upon the suction stroke; or again the exhaust valve may be *kept open* during the suction stroke, which also acts to prevent the opening of the inlet valve. By keeping the valve *partly closed* during the exhaust stroke only a part of the burnt gas is expelled, thus a full charge cannot be drawn into the engine; the expulsion of the waste gases through a restricted opening has the effect of absorbing some of the surplus power of the engine.

The control may be effected by hand, or automatically by the agency of a governor acting upon a throttle valve, or upon the exhaust valve mechanism; the governor acts to maintain the speed with certain limits, and it does so without attention, but it is frequently necessary to obtain a greater maximum of speed and thus of power than the governor allows for, so a device is provided to throw the governor out of action when required; this is termed an *accelerator.*

The Silencer

The sudden escape of the exhaust gases direct into the atmosphere produces a somewhat objectionable noise; the function of the silencer, muffler, or exhaust box, as it is variously termed, is to deaden this noise; it can be done only by imposing a greater resistance upon the engine, and the object of the designer is, while reducing this additional resistance to a minimum, to deaden the sound as far as possible. The various forms which the silencer takes in practice all act by allowing the gases from the engine to expand through a series of small openings in a large chamber, where they lose their pressure and escape into the atmosphere at a low speed and more or less continuously instead of in puffs. A form of construction is shown

in the diagram on p. 172. Here the silencer consists of three concentric cylinders closed at the ends; the gas led in at the top of the inner cylinder escapes through a series of holes near its lower end into the intermediate cylinder, from which it passes by a similar series of holes at the upper end into the outer cylinder; this in turn is provided with a series of holes in its lower end, through which the gas escapes in fine streams into the atmosphere. In another form of silencer a single cylinder provided with transverse perforated discs is used. Two silencers are sometimes arranged in series, and the gas is led from the first to the second by a pipe.

Cooling

The explosion of the charge is accompanied by the production of great heat, and a very high temperature is imparted to the walls of the cylinder and combustion chamber. It is necessary to keep this temperature within limits; if it rises too high, it has a serious effect in reducing the power which the engine can exert, for it is clear that on the suction stroke the incoming charge is expanded by the heat of the walls, and that with a very hot cylinder but a small charge suffices to fill it. Excessive heat has also the effect of decomposing the oil used for lubrication, of causing the distortion of the valves, cylinder and piston by unequal expansion, and the oxidation of the valves and their seats, which then rapidly wear away and cease to be tight, and of weakening the strength of the valve springs.

In small engines, such as those used for bicycles, it is found that cooling proceeds with sufficient rapidity by mere contact with the air, and to facilitate this action the cylinder walls are either formed very thin, or are provided with external webs to increase the radiating surface.

In larger engines special cooling devices are provided. Currents of air are sometimes caused to circulate round the

cylinder as in the case of the Lanchester engine, but usually a current of water is passed between the walls of the cylinder and combustion chamber and an outer shell or casing. The water after leaving the cylinder is cooled in a system of pipes, provided with flanges or ribs to increase the radiating surface, termed the radiator, which is placed so as to be fully exposed to the rush of air in the movement of the car. The radiator is usually not of large capacity, so a water tank is used in addition, and the radiator, tank and water jacket round the cylinder are connected by a system of flow and return pipes. The parts may be so arranged that the circulation takes place naturally, the heated water from the cylinder rising upwards to the radiator, the cooled water escaping at the bottom thereof, and returning to the lower end of the jacket. Perhaps more usually a centrifugal, rotary or other form of pump worked by the engine is introduced into the system of pipes to cause a positive circulation of the water. In some systems, as in the Cannstadt-Daimler cars, the water tank itself forms the cooler, being traversed by a large number of tubes through which air is drawn. The natural circulation system is, if less certain in action, also less complicated than the pump system, but as the water gradually boils away it involves the replenishing of the supply from time to time.

VIBRATION

In common with other road vehicles, but in consequence of its higher speed to a greater extent, the motor car is exposed to vibration from the inequalities in the surface of the roads. In addition, the petrol car in particular possesses a source of vibration peculiar to itself in the action of its motor. With a rotary motor, such as a steam turbine or an electro-motor, in which the power is supplied uniformly during a revolution, and in which the

rotating parts are well balanced, vibrations from this source should be inappreciable in extent. With a reciprocating engine, such as the steam engine or the petrol engine, on the other hand, two causes of vibration are at once apparent, one the reciprocating masses of the engine itself, and the other the inequalities in the turning effort exerted upon the crank shaft. The first may be overcome or modified by the use of two or more cylinders, so arranged that the pistons move in opposite directions, as in the case of a two-cylinder engine with the cranks opposed or set diametrically opposite each other on the crank shaft, or by the use of balance weights, etc.

The second cause, the inequality of the turning effort, is, however, of greater importance at all events in the petrol engine. A certain inequality is inevitable from the action of the connecting rod and crank, but in the single-cylinder engine it is intensified by the fact that there is but one driving impulse for every two revolutions of the crank shaft. During that impulse, extending over half a revolution (it is really even of less duration than this), sufficient power has to be imparted to the shaft to carry the vehicle onwards while the remaining one and a half revolutions of the cycle are performed. This power is stored up in the fly wheel and rotating parts, and in the car generally in the form of momentum; their velocities are suddenly increased during the period of the impulse, and then fall off towards the end of the cycle with the expenditure of the power; the progression is in fact effected by a series of jerks. The moving masses, in virtue of their inertia, resist the acceleration of speed which the piston under the pressure of the expanding gases tends to impart to them through the crank pin. Relatively to this acceleration the crank pin and connecting rod may be for the moment regarded as fixed, the pressure on the cylinder end then tends to swing the whole engine upwards about the crank pin as a centre. This is repeated at every working stroke, and appears to be

the main cause of vibration in these engines. When the car is in motion the engine vibrations are absorbed in the movement of the car. They are more noticeable when the car is stationary and the engine running, particularly if the engine is governed by preventing the opening of the exhaust valve, as the impulses then become fewer than ever.

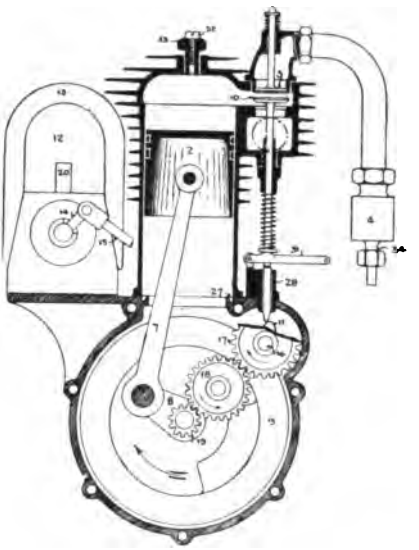
Obviously the remedy is to make the driving impulses smaller in extent and greater in number, in order to approximate as closely as possible to the production of a uniform turning effort on the crank shaft. This is effected by the use of two, three, or four-cylinder engines in place of the single cylinder, and the tendency of recent practice is decidedly in this direction. Still it is to be borne in mind that the improvement is effected at the cost of having an increased number of working parts liable to derangement, and that for many purposes the simplicity of the single-cylinder engine may fully compensate for any inconvenience resulting from its mode of action.

The Simms Engines

Many motor-car manufacturers build their own engines, others obtain them from firms who make a speciality of the construction of petrol engines. The De Dion-Bouton Company are the largest makers, and their engines are referred to in a succeeding chapter. In this country the Simms Manufacturing Company build engines in sizes ranging from two horse-power upwards, all fitted with the Simms-Bosch electrical ignition and variable-timing gear and with float-feed spray carburetters. The two horse-power engine, intended for bicycles, etc., has an air-cooled cylinder sixty-five millimetres bore by seventy stroke; it gives off two horse-power at the crank shaft when running at 200 revolutions per minute, and its speed may be varied from 400 to 2500 revolutions per minute. The fly wheels,

cam shaft and gearing are enclosed in the crank chamber. The inlet valve may be removed, after uncoupling the union on the supply pipe, by unscrewing the dome above it, the lower edge of which forms the valve seat; the exhaust valve may then be drawn out through the opening, after removing the pin which holds the spring on its stem. To facilitate starting and the control of the engine an exhaust-valve lifter is provided; this consists of a lever which may be caused to press on the valve stem to keep the valve open when desired. Lubrication is effected by a charge of oil introduced into the crank chamber; the oil is splashed by the movement of the crank over the crank pin, shaft, gearing, cam shaft, etc., and into a groove in the lower end of the cylinder, into which the lower edge of the piston dips at each stroke.

The larger engines



2. Piston.
3. Induction Valve.
4. Carburetter.
7. Connecting Rod.
8. Crank.
9. Fly Wheel.
10. Exhaust Valve.
11. Exhaust Cam.
12. Magneto Machine.
13. Magnets.
14. External Arm of Magneto.
15. Magneto Connecting Rod.
16. Half-speed Shaft.
17. Half-speed Pinion.
18. Intermediate Pinion.
19. Full-speed Pinion.
20. Terminal.
27. Lubrication Groove.
28. Exhaust Rod Guide.
31. Exhaust Valve Lifter.
32. Screw for admission of Paraffin.
33. Screw for attaching to Frame.
34. Filter.

SIMMS' TWO HORSE-POWER PETROL ENGINE, WITH AIR-COOLED CYLINDER.

have water-cooled cylinders; the three and a half and the six horse-power engines have single cylinders, those above six horse-power have two cylinders.

The illustration on p. 172 represents diagrammatically the arrangement of the eight horse-power engine. It will be noticed that the lift of the inlet valve is regulated by means of a lever engaging with its stem; this lever is controlled by hand to prevent the valve from opening to its full extent when desired.

The twelve horse-power engine has two cylinders 110 millimetres diameter by 100 millimetres stroke; it gives off twelve horse-power at 1000 revolutions per minute, and fourteen horse-power at 1200.

The two cylinders, with their water jackets, are cast in one piece without water joints in the combustion chamber; the pistons of hard cast iron are each fitted with three rings, and the inlet and exhaust valves are turned down from bars of mild steel; the cranks are also formed of mild steel; the bearings have large surfaces lined with white metal, and the connecting rods are steel stampings. In the inlet pipe is a throttle valve controlled by a governor on the cam shaft. The variation in the timing of the ignition is effected by moving the lower end of the trip rod sideways over the cam so that this makes contact with its lower end sooner or later as required; the range of speed is from 300 to 1800 revolutions per minute. The fly wheel in this and the other sizes above three and a half horse-power is outside the crank chamber.

CHAPTER XII

PETROL CARRIAGES OF TO-DAY—BRITISH

THE tendency towards a general uniformity in the main features of the petrol car has been very marked during the last year or two, and the greater number of cars now turned out may be said to belong to a standard type. The standard car has a vertical engine placed under a hood or bonnet in front, and arranged with its crank shaft lying lengthways of the car. The crank shaft is coupled by a cone friction clutch to another shaft, extending rearwards through a gear box, which drives another parallel shaft by means of any one of a series of pairs of toothed wheels of different ratios.[1] The wheels on one shaft are so mounted that, while they cannot rotate independently of it, they may be moved endways to slide any one of them into gear with the corresponding wheel on the other shaft, according to the speed required. To produce rotation of the second shaft in the reverse direction, as when the car is required to move backwards, an intermediate idle wheel is caused to gear with a wheel on each shaft. The second shaft transmits the motion, by means of bevel toothed wheels, to a shaft extending across the car, at the ends of which are chain wheels connected by chains to corresponding wheels fixed to the rear road wheels. The cross shaft is fitted with a "balance" or "compensating" gear, which will allow one of the road wheels to move faster than the other. In an alternative arrangement, much used for light cars, the road wheels, instead of running loose on a fixed axle, are fixed to a revolving or live axle, to which motion is imparted by

[1] The non-technical reader would do well to refer to Chapter XVII. for an elementary explanation of the various forms of gearing in use.

bevel wheels from a shaft extending longitudinally from the gear box.

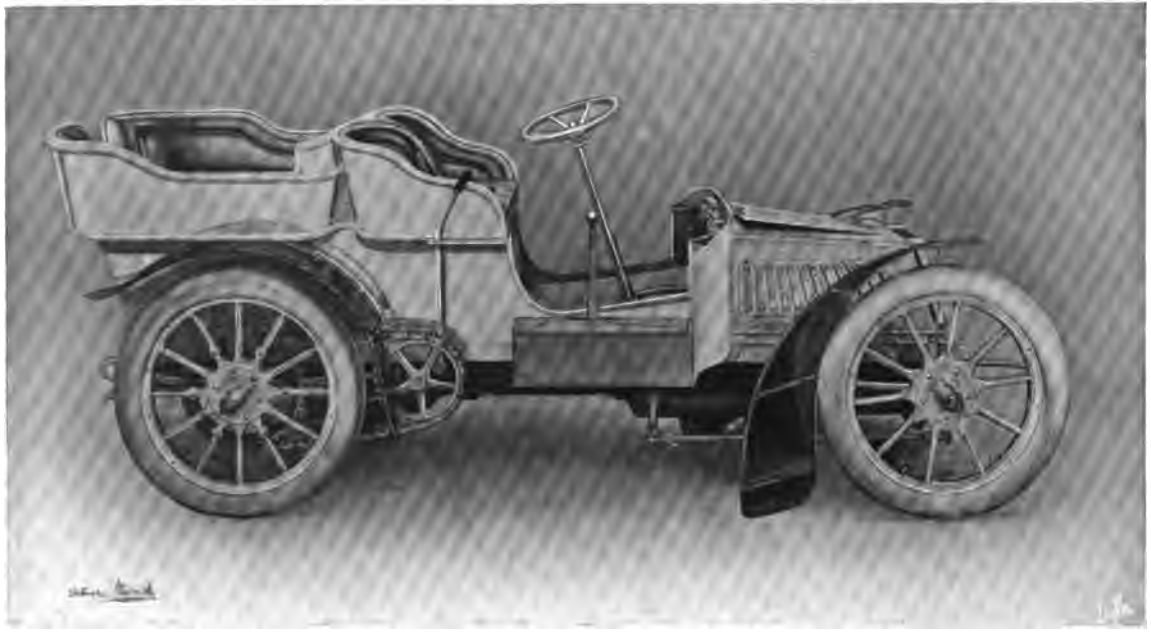
The engine may have one, two, or four cylinders which are cooled by circulating water through casings or jackets enclosing them. The radiator, or system of piping, for cooling the heated water, as it leaves the cylinder jackets, is placed in some exposed position, usually in the front of the car. The ignition of the charge is effected by an electric spark, produced between the terminals of a sparking plug, by means of an accumulator, induction coil with a trembler, and a rotating contact maker. The governing is effected, in general, by throttling the supply of the mixture of petrol vapour and air to the engine.

As to the carriage work, the tonneau body is very popular, but most of the makers fit other forms, phaeton, etc., as well.

The Daimler Cars

The Daimler Company was the first company organised in England for the purpose of building motor cars. It was formed in the early part of the year 1896. The productions of the company speedily gained a reputation for sound and reliable workmanship and good design, and obtained for them a large and distinguished *clientèle*, including His Majesty the King, for whom the company have already built four carriages and are constructing a fifth.

Although their cars were capable of good work on the road, and the six horse-power car in particular, of which some 300 have been turned out, has many fervent admirers even to-day, the company felt of late that they were not keeping pace with the advance of the art and decided to reorganise their designs, with the result that they are now sending out a series of cars which differ considerably from those of past years, and of which it is not too much to say that they are in the first rank, whether as regards design,



DAIMLER STANDARD CAR, WITH TONNEAU BODY.

workmanship, ease of control, finish or comfort, and it may be expected with confidence that when they become more widely known that they will be in great demand.

The company are now building cars in three sizes, nine, twelve, and twenty-two horse-power, to what may be termed the standard type, vertical engines under a bonnet in front, crank shaft lying longitudinally in the frame, sliding-wheel variable-speed and reverse gear, bevel drive to differential shaft, and thence chains to rear road

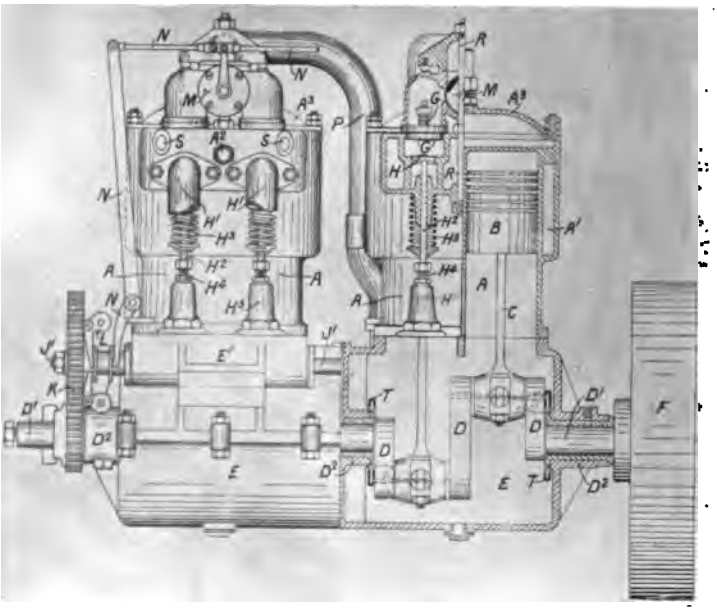
DAIMLER-MANVILLE CAR.
(The three seats in the rear are entered from the front of the car, one of the front seats being hinged to admit of being turned up.)

wheels. The design, although following in its broad lines the standard type which has so well approved itself in practice, presents many special features, and is remarkable for careful attention to detail throughout. One result of the change has been to produce a considerably lighter while equally strong car. The frame and gearing of the twelve horse-power car, for instance, now weigh fifteen hundredweights as against twenty-three hundredweights for the old cars.

For the purposes of a detailed description the twelve

horse-power car is selected; the points of difference in the nine and twenty-two horse-power cars will be indicated afterwards.

Engine.—The motor is a four-cylinder engine which, running at a speed of 900 revolutions per minute, is capable of developing fifteen horse-power at the crank

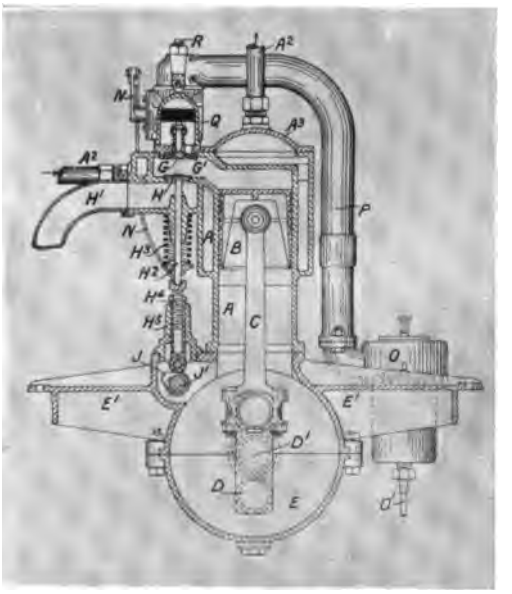


A. Cylinder.
A¹. Water Jacket.
A². Water Pipe.
A³. Cover.
B. Piston.
C. Connecting Rod.
D. Crank.
D¹. Crank Shaft.
D². Bearings.
E Crank Chamber.
E¹. Wings on Crank Chamber.
F. Fly Wheel.
G. Inlet Valve.
G¹. Inlet Valve Seating.
H. Exhaust Valve.
H¹. Exhaust Pipe.
H². Exhaust Valve Stem.

DAIMLER TWELVE HORSE-POWER ENGINE, SIDE ELEVATION PARTLY IN SECTION.

shaft. The cylinders are cast in pairs and are in one piece with the water jackets; they are formed with closed ends, there being no joint whatever between the combustion chamber and the water space, so that there is no possibility

of a leakage of water into the combustion chamber through a faulty joint. The cylinders are bolted to a crank chamber cast in aluminium and in two parts, the division being in the horizontal plane of the crank shaft; the upper part is formed with wings for securing the engine to the frame. The crank shaft is supported in bearings formed in the ends



H³. Exhaust Valve Spring,
H⁴. Reciprocating Rods.
H⁵. Guides for Reciprocating Rods.
J. Cam.
J¹. Cam Shaft.
K. Gearing for Cam Shaft.
L. Centrifugal Governor.
M. Throttle Valve.
N. Throttle Valve Connections.
O. Carburetter.
O¹. Petrol Supply Pipe.
P. Mixture Pipe.
Q. Bridge Pipe.
R. Holding-down Bolt.
S. Holes for Ignition Plugs.
T. Lubricating Rings.

DAIMLER TWELVE HORSE-POWER ENGINE, CROSS SECTION.

of the chamber and in an intermediate bearing formed in a transverse web which divides it in the centre. The pistons are light iron castings formed with strengthening ribs and with lips at their open ends; they are coupled by steel

connecting rods to the crank shaft, which has two cranks directed one way and two in the opposite way, whereby a working stroke occurs regularly twice in each revolution of the shaft. The inlet valves, normally kept closed by springs, are opened by atmospheric pressure on the suction stroke in the usual way. The exhaust valves, placed directly below the inlet valves, are operated by cams which act through reciprocating rods fitted in guides below the valve stems. The cam shaft and cams are enclosed in the crank chamber, and the gearing for driving them from the crank shaft is external to the chamber.

Carburetter.—The carburetter is of the float-feed spray type with the jet impinging against a pulverising cone; it is fitted with a jacket supplied with hot water through a by-pass in the pipe leading from the cylinder jacket to the radiator. The Daimler Company find this method of warming to give more uniform results than the use of the exhaust gases. The nozzle or jet pipe is provided with a plug or needle valve which may be adjusted to vary the supply of petrol. The float chamber is made much deeper than usual in order to provide a space below the valve nozzle for the deposit of sediment or foreign matter carried in by the petrol; it can be drained out without disturbing nuts or screws.

Governing.—The engine is governed by throttling the supply of mixture between the carburetter and the inlet valves. For this purpose a centrifugal governor, mounted on the forward end of the cam shaft outside the crank chamber, is connected to throttle valves placed in the inlet pipes immediately above the inlet valves, there being one throttle valve for each pair of cylinders. The throttle valves are similar to the well-known Corliss valves used in steam engines; they consist of segmental plates mounted to rock to and fro and to uncover more or less passages formed in a circular chamber. This chamber is formed in a bridge pipe which spans the inlet valves of a pair of cylinders and has an opening on top, over which

fits the end of the inlet pipe. This end is held down by a single bolt which at the same time holds in place the bridge pipe and the seatings against which the inlet valves work. The governor can be thrown out of action by hand to vary the speed beyond its limits.

Ignition.—Both tube and electric ignition are fitted, and the same attachment to the cylinder is made to serve for both. The commutator for the electric ignition is driven by chain gearing from the cam shaft; it is mounted on the dashboard in view of the driver, and is provided with a hand-controlled device for advancing or retarding the time of ignition.

Cooling.—The cylinder cooling apparatus is all arranged near the engine. The heated water from the cylinder jackets passes to a radiator in front of the car, then to a tank immediately below, and back to the jackets. The circulation is maintained by a small centrifugal pump driven by chain gearing.[1] The radiator consists of a series of small flanged tubes fixed at the ends in vertical chambers of aluminium.

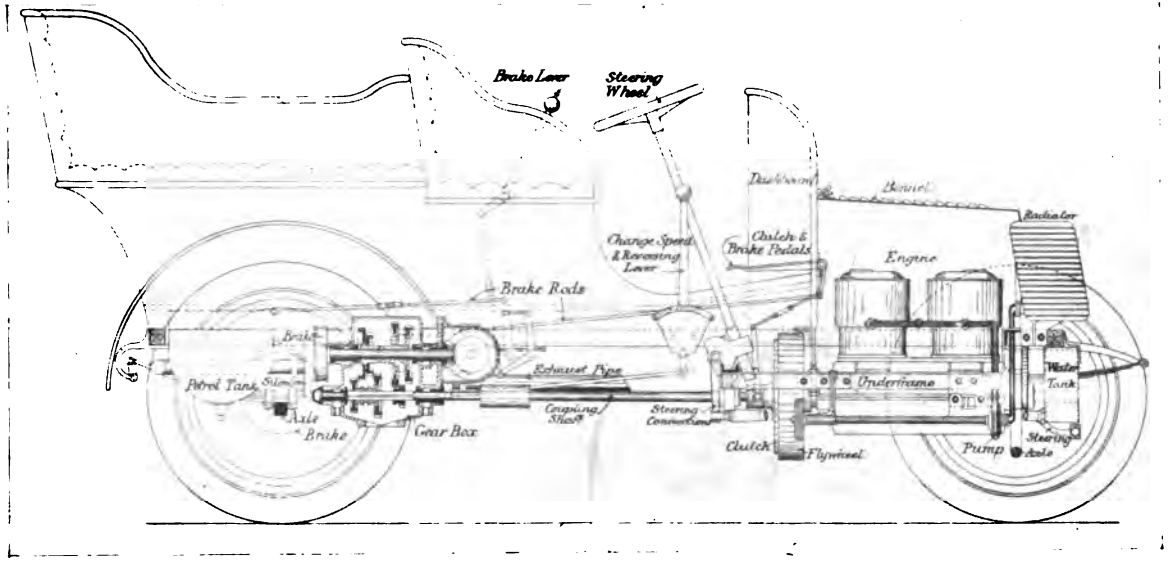
Clutch.—The engine shaft extends lengthways of the car, and carries on its rear end a fly wheel, in which is formed a hollow conical surface. This constitutes one member of the friction clutch; the other member is mounted on a coupling shaft in the same line with the engine shaft, and extending from it to the gear box; this member is pressed into contact with the first to effect the transmission of power by means of a spring; it is, while incapable of rotating in relation to its shaft, free to slide thereon, and may be drawn back to disconnect the engine from the gearing, by pressure exerted on a pedal. The surfaces of the clutch members are plain cones, but the male cone has a leather band round it, between which and the nose of the cone is interposed a spring whereby the engaging edge of the leather band is normally held at some little distance

[1] In the drawing the pump is shown as driven by a friction wheel in contact with the fly wheel, but this plan has been abandoned.

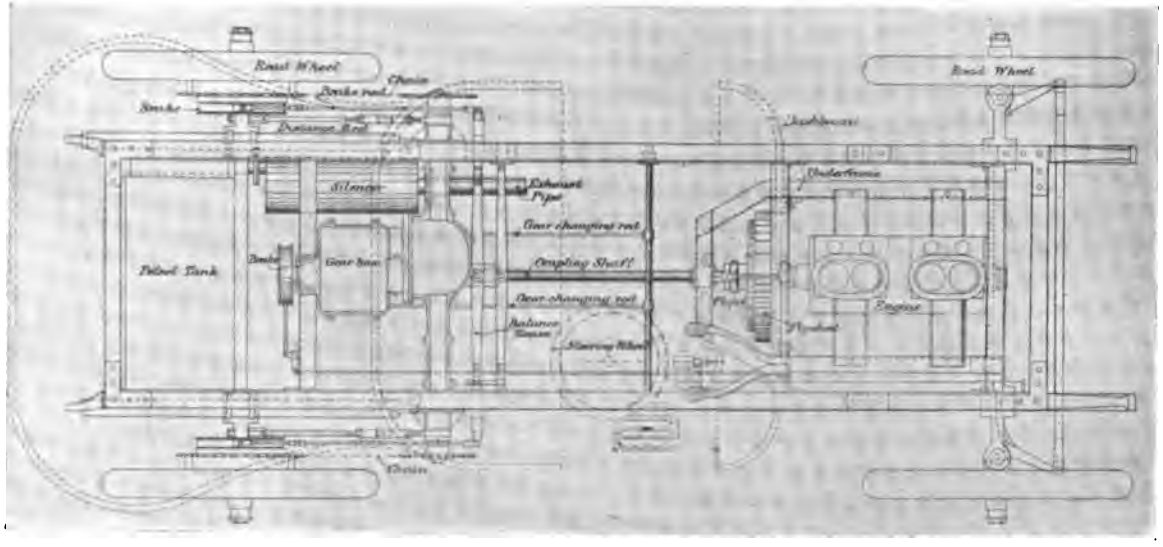
away from the cone; this ensures the gradual and smooth engagement of the clutch.

Gearing.—The longitudinal coupling shaft extends rearwards to the gear case, between which and the clutch there is a considerable open space, and is connected to the first-motion shaft, supported therein, by a flexible coupling. The second-motion shaft, mounted in the gear case parallel to and above the first-motion shaft, is driven from it by any one of a series of pairs of wheels of different ratios. The first-motion shaft is square in section, and its wheels are movable endways to bring the required gear into action, according to the speed required; for reversing, one of the wheels is engaged with an intermediate wheel on a separate axle which is constantly in mesh with a wheel on the other shaft. In the Daimler construction, the movable or sliding wheels are mounted in pairs on two short sleeves; these are coupled by rods, one to a spindle, and the other to a sleeve thereon, which may be moved independently of each other by a single hand lever at the side of the car. The quadrant in which this lever works is formed with two guide slots, which communicate with each other by a central gate, and the lever is formed with a hinge joint, in order that, when in a vertical position with all the gearing disengaged, it may be swung sideways from one slot into the other. When in one slot it is in position to work one sleeve, when in the other slot, the other sleeve; and it is moved to one end of the slot or the other, according as one wheel or the other of the pair on the sleeve is to be engaged. Thus with a single handle three changes of speed forward and a reverse may be obtained, or, as in the twenty-two horse-power car, this handle may be arranged to control four speeds forward, and a separate handle be provided for reversing.

The second-motion shaft drives, by bevel wheels, a transverse shaft fitted with the differential gear, and carrying at each end a chain wheel from which the chain wheels on the rear road wheels are driven. This shaft although



DAIMLER TWELVE HORSE-POWER CAR, SIDE ELEVATION.



DAIMLER TWELVE HORSE-POWER CAR, PLAN.

placed in front of the change gearing, is still well in the rear of the car, so that comparatively short chains are required. The gear case is made of aluminium; it encloses the change gearing, the bevel wheels and the differential gearing, and is formed with long sleeves which extend out to, and are supported on, the side members of the frame; the differential shaft has its bearings in these sleeves. At the rear the case is supported on a cross member of the frame. Doorways are formed in the top over the change gearing and over the differential gearing.

Brakes.—A brake drum, which may be cooled by water, is secured on the rear end of the second-motion shaft; to this a brake band is applied by depressing a pedal. Other brake drums on the rear wheels are fitted with bands which are tightened by a hand lever on the side of the car; this hand lever is linked to a lever which extends across the frame, and is pivoted at one end so that it may swing in a horizontal plane; this lever is linked to the centre of another transverse lever, the ends of which are connected to the brake bands; the second lever thus forms a balance beam, and divides equally the pull exerted upon the hand lever. All the brakes are adapted to resist rotation in the backward as well as in the forward direction, and they are linked up to the clutch-releasing mechanism, in order that when either set is applied the clutch may be drawn out of action automatically.

Steering.—The front wheels are carried by an axle constructed on the Ackermann system, *i.e.*, it consists of a fixed central portion to which are pivoted two end portions on which the wheels rotate. The end portions are formed with arms, which are coupled together and to the steering mechanism, in order that they may be simultaneously moved into the desired angle with the central portion. The steering mechanism consists of a hand wheel upon an inclined spindle, which acts through a worm and segment wheel, and levers and links. The handles for controlling the period of ignition and for

throwing the governor out of action are mounted on the pillar which supports the steering wheel.

Wheels.—The wheels are of wood, artillery pattern, fitted with pneumatic tyres; they run loose on their axles, and the rear wheels have fixed to them the chain wheels and brake drums.

Frame.—The frame is also of wood strengthened by steel flitch plates; it rests upon the axles by means of laminated springs, and adjustable distance rods are provided at each side of the car to keep the ends of the rear axle at uniform distance from the differential shaft. The engine is carried on an underframe composed of steel angle bars.

The petrol tank extends across the rear of the frame; it is so placed that the petrol will flow to the carburetter by gravity for starting the engine; but when once the engine is at work the pressure of the exhaust gases is relied upon to force the petrol to the carburetter.

The silencer is also mounted in the rear of the frame, at the side of the gear box.

The nine horse-power car is fitted with a two-cylinder engine; it is in other respects the same as the twelve horse-power.

The twenty-two horse-power car has a four-cylinder engine in which the old Daimler practice of governing by the exhaust valves has been retained; a hand-controlled throttle valve is however fitted in the inlet pipe.

The Daimler Company have for some years employed the system of governing on the exhaust which is still retained in their twenty-two horse-power engine. The exhaust valve stems are coupled by spring connections to extensions termed "diggers," which normally engage with pivoted intermediate pieces, the ends whereof rest upon the cams and are moved up and down as these rotate and transmit their upward movements through the diggers to the valve stems. Upon a rise of speed above the normal, the ends of the diggers are pushed outwards, clear of the intermediate pieces, so that these no longer act upon the

valves, which accordingly remain closed. The effect of this is to retain the burnt charge in the cylinder, and thus to prevent the inlet valve from opening and admitting a fresh charge. The diggers are actuated by a centrifugal governor mounted on the cam shaft, and adapted to move to and fro a sleeve also mounted on the same shaft. The sleeve is formed at one part concentric with the shaft, and at other parts eccentric. The diggers are connected by links to levers on the same axis with which is another lever, the free end whereof bears upon the sleeve. When the engine is running at the normal speed, or at any lower speed, the governor holds the sleeve in such a position that its concentric part rotates in contact with the lever, which therefore is not moved. When the speed rises above that for which the governor is set, the sleeve is pushed endways and its eccentric part comes opposite the lever, which is then rocked as the shaft rotates, and thus pushes the digger off the intermediate piece. This is effected first for one cylinder only, and if the speed still continues to rise in spite of the cylinder being "cut out" or rendered inoperative, the sleeve is pushed still further forward to bring a larger eccentric against the lever, which is then rocked to an extent sufficient to push the digger of the second cylinder out of action. This digger, it should be explained, is coupled to its lever by a telescopic link, arranged to take up in itself the movement which causes the first digger to be thrown out.

The Wolseley Cars

These cars are driven by horizontal engines placed in front with the crank shaft lying across the car and geared by a chain to the first-motion shaft of the variable-speed gearing, which is of the sliding-wheel type. The second-motion shaft of this gearing carries the compensating gear and communicates motion to the rear wheels of the car by a chain at each end. The petrol tank is in front of the

dashboard, under the bonnet which covers the engine; the petrol flows from it by gravity to a float-feed spray carburetter. A reserve of petrol may be carried in an extra tank fitted under the rear of the car; from this the liquid may be forced by means of air pressure produced by a tyre pump through a connecting pipe to the tank in front of the dashboard. This tank is provided with a gauge glass on the dashboard in view of the driver, by which its contents may be seen at a glance. The fitting which connects the gauge glass with the inside of the tank also serves to connect the supply pipe to the carburetter; it is fitted with a three-way cock by which communication with the gauge glass may be cut off in the event of this being broken. In the pipe leading from the carburetter to the engine are two throttle valves, one operated by a lever on the steering pillar, the other connected to the pedal which operates the brake on the second-motion shaft. The application of this brake is therefore accompanied by the automatic reduction of the supply of gas to the engine; but this valve does not allow the supply to be entirely cut off, and it is impossible to stop the motor by its means. This feature is a valuable adjunct in controlling the car in crowded streets. The ignition is on the high-tension electric system, with woven-glass accumulators and coils. No governor is employed, the motor being controlled entirely by hand.

The standard size of engine has cylinders four and a half inches diameter by five inches stroke. On the five-horse-power car, the smallest which the Wolseley Company make, one cylinder is used; on the ten horse-power, two cylinders are placed side by side with the valve boxes in front of the car, and work a two-throw crank shaft having the cranks in line; on the twenty horse-power car this arrangement is duplicated on the rear side of the crank shaft, and one fore and one aft cylinder work on each crank. At the normal speed of 750 revolutions per minute, these engines develop respectively five, ten and twenty-one horse-power on the friction-brake dynamometer.

In addition to the standard cars the company have recently brought out a seven-horse power car having a two-cylinder engine which runs at 900 revolutions per minute; and, besides the tonneau body shown in the illustration, they fit phaeton, wagonette, cab and other forms of body upon the standard frames. They have also built racing cars with engines of special dimensions.

In the detailed description which follows the con-

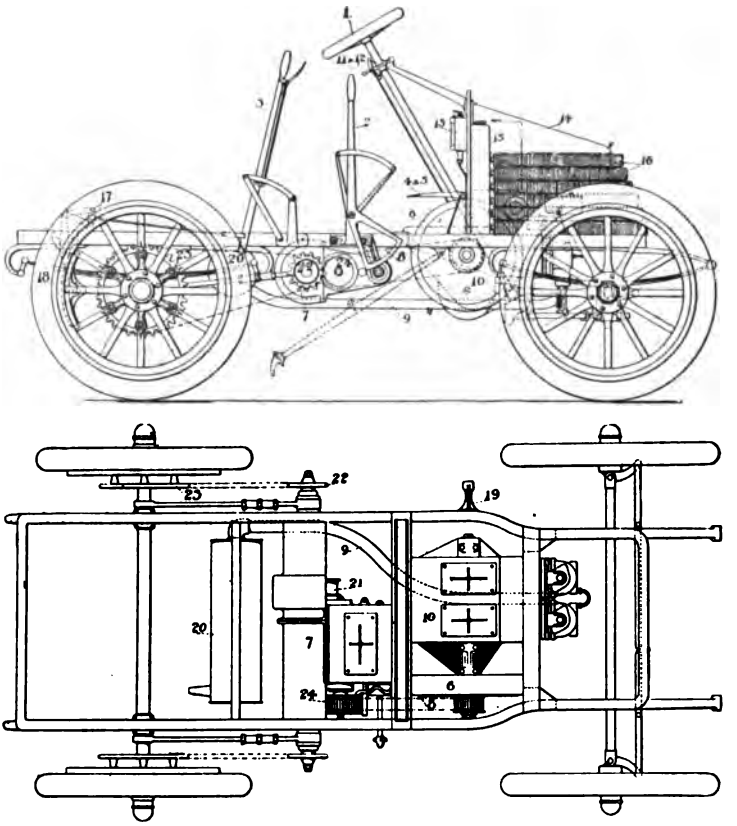
WOLSELEY TWENTY HORSE-POWER STANDARD CAR.

struction kept in view more particularly is that of the ten horse-power car.

Engine.—The engine casing is a casting of an aluminium alloy, it is made in two sections which are bolted together; the upper and larger section receives the cylinders and forms the upper half of the crank chamber, which is completed by the lower section.

The cylinders are plain shells of cast iron fitted in side by side by means of ground conical joints at the outer ends, and by means of red lead joints at the inner ends. Square flanges formed on the outer ends fit against facings on the casing and are secured by bolts and nuts. These bolts are prolonged for the purpose of holding on the combustion chambers, which are separate castings of iron

fitted to the cylinder ends by means of ground joints, separate nuts are employed, however, in order that the combustion chambers may be removed without interfering with the cylinders. The use of ground joints obviates the necessity for packing. The pistons are also plain cylindrical shells, but are closed at one end, that remote from the crank shaft; near the closed end three grooves are turned to receive the piston rings. The rings are split, and between the ends of each a small pin is driven into the piston to keep it from moving round, and thus to prevent the split ends of the three rings from coming into line with each other and so forming a free passage for the escape of gas from behind the piston. Near the opposite end of the piston another groove is formed to retain the lubricant. Pins forged on the ends of the connecting rods engage in eye bolts which pass through the bottom of the piston and are secured by nuts which are locked by slightly riveting over the ends of the bolts. The crank shaft, made of forged steel, is supported at the ends in long bearings fitted in the side walls of the casing and, between the cranks, by a bearing in a transverse web of the casing. The cranks and balance weights are forged solid with the shaft, as is also a disc to which the fly wheel is bolted; this construction ensures true running. The fly wheel forms one member of a friction clutch, its outer face being formed into a conical recess; the other member of the clutch is formed of an aluminium disc secured to a malleable cast-iron centre, and is loose upon the crank shaft; the edge of the aluminium disc is coned and lined with leather. Normally the loose member is forced into contact with the fly wheel by a spring encircling the end of the shaft; to disconnect the engine from the gearing it is drawn back, against the resistance of the spring, by means of a pedal acting through a system of levers and links. The crank shaft drives by means of toothed wheels the half-speed or cam shaft, also enclosed in the casing, the cams upon which actuate the exhaust valve levers.



1. Steering Wheel.
2. Change-speed and Reversing Lever.
3. Hand Lever for Brake Shoes, 18 on Rear Wheels, acting through Equalising Levers 17.
4. Pedal for Band Brake 21 on Second-motion Shaft.
5. Pedal for Clutch.
6. Fly Wheel and Friction Clutch.
7. Gear Box.
8. Chain connecting Wheel on Engine Shaft to Wheel 24 on First-motion Shaft.
9. Exhaust Pipe.
10. Engine.
11. Ignition Lever.
12. Throttle Lever.
13. Lubricators.
14. Bonnet.
15. Water Bottles.
16. Radiator.
19. Starting Handle Bracket.
20. Silencer.
22. Chain Wheels on Second-motion Shaft.
23. Chain Wheels on Rear Road Wheels.

WOLSELEY CAR, ELEVATION AND PLAN WITHOUT BODY.

In order to facilitate the starting of the engine the exhaust valves may be kept open during the first half of the compression stroke, to relieve the compression, by means of auxiliary cams on the half-speed shaft, which by means of a knob on a spindle projecting through the side of the casing may be slid along it over the fixed cams. The exhaust valves are fitted to work vertically in the bottoms of the combustion chambers; their stems project outwards below to engage with spiral springs, which draw the valves down upon their seats, and with the outer ends of the operating levers. The levers extend into the engine casing, being pivoted at the points at which they pass through it, and engage at their inner ends with the cams. The exhaust branches on the combustion chambers are inclined towards each other, and are connected by a forked pipe to the silencer, which is mounted behind and parallel to the gear box. The inlet valve boxes are bolted to the tops of the combustion chambers; the valve stems project upwards and are fitted with springs outside.

Regulating.—The throttle valves are fitted across the inlet pipe between the carburetter and the valves; they consist of two short metal strips in which openings are formed, and are adapted to slide to and fro. When the openings coincide with the passage through the pipe, the mixture of petrol vapour and air flows without obstruction, and the maximum supply passes to the engine; when either valve is moved to block the passage more or less, the supply is correspondingly reduced. A stationary partition is interposed between the valves in order to prevent one from drawing the other with it by friction.

Ignition.—The contact breaker is fitted on the end of the cam shaft, it takes the form of a disc of fibre fitted with a metallic wiper pressed outwards by a spring; this rotates in a circular box fitted loosely on the end of the shaft, and formed with one or more sockets to receive the contacts from which the conducting wires are led to the

induction coils. By means of a small lever on the steering pillar the box may be turned to regulate the position in the piston stroke at which ignition is to take place and thus the speed of the engine. The ignition plugs are fitted in the ends of the combustion chambers.

Cooling.—The space between the cylinders and the casing forms a water jacket for the cylinders, and the combustion chambers are also cast with double walls to form water jackets. The latter are entirely distinct from the cylinder jackets and provided with separate inlet and outlet connections, so that there is no water joint between the combustion chambers and the cylinders. The water circulating through these jackets is cooled in a radiator composed of a pair of vertical boxes or bottles of aluminium placed in front of the dashboard, one on each side of the petrol tank. These are connected by a number of bent pipes of copper lying horizontally one above the other, and forming a sort of enclosure for the engine. On the pipes are threaded large numbers of small brass plates, which are soldered in place, and serve to increase the radiating surface and thus to enhance the cooling effect. The water is circulated through the radiator and round the cylinders and combustion chambers by a rotary pump fitted with a large strainer, and worked by screw gearing from the cam shaft, but in case the pump fails the position of the radiator above the motor ensures a certain degree of circulation being maintained. The amount of water carried is very small, only about one and a half gallons in the ten horse-power car, but the cooling is found to be quite efficient.

Gearing.—The sliding member of the clutch on the engine shaft carries a chain wheel which is connected by a Renold's chain to a wheel on the first-motion shaft of the variable-speed and reversing gearing. This gear is of the sliding-wheel type, the first-motion shaft carrying a series of wheels of different diameters which may be moved end-

ways to bring them, one by one, into engagement with corresponding wheels on the second-motion shaft, or, for reversing, to bring one of them into gear with an idle wheel which runs on a fixed stud, and is permanently in gear with one of the wheels on the second-motion shaft. This shaft is fitted with the compensating gear, composed of spur wheels, and has on its ends chain wheels which are connected by roller chains to other chain wheels fitted on the hubs of the rear wheels of the vehicle and bolted to alternate spokes. The shifting of the sliding wheels is effected by a single hand lever at the side of the car; a toothed sector formed on this lever gears with a pinion on a spindle which passes through the gear box, parallel to the shafts; a fixed bar also extends across the gear box, parallel to the shafts, and serves as a guide for two forks, the ends of which engage in annular grooves formed in the bosses of the sliding wheels, which are formed in pairs, and in cam grooves cut in a cylinder secured upon the spindle. Thus when the hand lever is turned, and the cylinder rotated, the cam grooves, acting through the forks, move the sliding wheels endways. The hand lever locks in its quadrant in any one of a series of positions corresponding to disengagement of all the wheels and to the engagement of the different speeds forward and the reverse motion. Recently an additional cam has been mounted on the spindle outside the gear box; the function of this is to move the chain wheel itself endways, and thus to disconnect it from a jaw clutch by which it is secured to the shaft, so that when the gear is being changed the shaft is automatically uncoupled from its driving means. The arrangement in the twenty horse-power car is somewhat different; the auxiliary cam is there placed inside the gear box, and shifts to and fro a jaw clutch placed between the pairs of wheels on the shaft. In this car too the driving connections between the engine and the first-motion shaft are duplicated, there being chain wheels at each end of the crank shaft and the first-motion shaft. The chain between the engine and first-motion shaft is

tightened by sliding the gear box bodily along the frame, or, in the smaller sizes of car, by swinging it about the second-motion shaft as a pivot. The chains from the second-motion shaft to the road wheels are tightened by adjustable stay rods which connect the rear axle to the second-motion shaft.

Brakes.—On the second-motion shaft is a drum, adapted to be charged with water for cooling purposes, to which is applied a band brake actuated by a pedal; the coupling link from the pedal is connected to a bell crank lever, to which the ends of the brake band are connected in such positions that when the pedal is depressed both ends of the band are pulled; by this arrangement the brake is rendered effective for opposing rotation of the drum in either direction. The band is lined with wood. The brakes for the rear wheels of the vehicle are applied by a hand lever at the side of the car; in the ten horse-power and smaller cars they take the form of blocks or shoes, which are pressed against the insides of brake rims secured to the wheel rims; in the twenty horse-power car band brakes are used. The shoes are lined with walrus hide, and of course act equally well whether the car is going one way or the other. The brakes on the opposite sides of the car are connected by a system of equalising levers to balance the pressures which they exert.

Lubrication.—The efficient lubrication of a high-speed machine, such as the petrol motor, is a matter of the highest importance. In the Wolseley cars it has been very carefully worked out, and all the important bearings are supplied with oil from oil boxes fixed on the dash board in front of the driver. These boxes are made of aluminium, and are provided with gauge glasses by which the amount of their contents may be seen. In the ten horse-power car, there are two such boxes, each fitted with six sight-feed lubricators which are connected by small copper pipes to the pistons, crank pins, crank shaft and gear box bearings. A sight-feed lubricator, it may be explained, is one in which

the oil drops through a small chamber fitted with a window so that the rate of feed may be ascertained by counting the number of drops in a given time. The supply is adjusted by a screw or the spindle of a valve which fits the delivery opening in the oil box. The pistons, of course, require most lubrication; they take twenty drops per minute as against five for each of the outer crank shaft bearings. A cock is provided in the crank chamber to allow the accumulation of spent oil to be drained off from time to time. Splash lubrication is not countenanced by this firm. The same lubricant is used for all these bearings. Price's gas-engine oil is that recommended. This may also be used for the road wheels, the caps of which have holes through which the lubricant may be introduced. The gear box is charged with grease, and the clutch, steering gear, contact breaker and pump are fitted with grease lubricators. The arrangement for supplying oil to the crank-pin bearing is very neat; the pipe from the sight-feed lubricator discharges into an annular recess formed round the crank shaft in one of the webs of the crank; from this recess a hole is drilled diagonally through the web to the surface of the crank pin; as the crank rotates, the oil is thrown out by centrifugal force.

Steering.—The steering is effected through a worm and wheel, which work in a box clamped to the front axle. An arm formed in one piece with the worm wheel is coupled by links to the steering arms on the pivoted axle ends which carry the front wheels. The worm is worked by a universally-jointed spindle and bevel gearing from the inclined steering spindle; this is supported at its lower end in the box enclosing the bevel gearing, which is bolted to the bottom of the motor casing, and, at its upper end, by an inclined bracket of aluminium fixed to the dash-board. The steering wheel is of aluminium, with a walnut wood rim. The use of the worm gearing, while allowing the hand wheel to control the road wheels, prevents these from reacting upon the hand.

Wheels.—The road wheels are of wood, artillery pattern; their hubs are fitted with two rows of ball bearings at each end. Any kind of tyre is fitted as required, but the company recommend Clipper-Michelin pneumatic tyres for speeds of over twenty miles per hour, and solid tyres for lower speeds, and where economy is an object

Frames.—Each car frame is made from a single bar of channel steel, bent to the required outline, the ends of which are joined together at the rear of car by a riveted fish plate or butt strap.

The Napier Cars

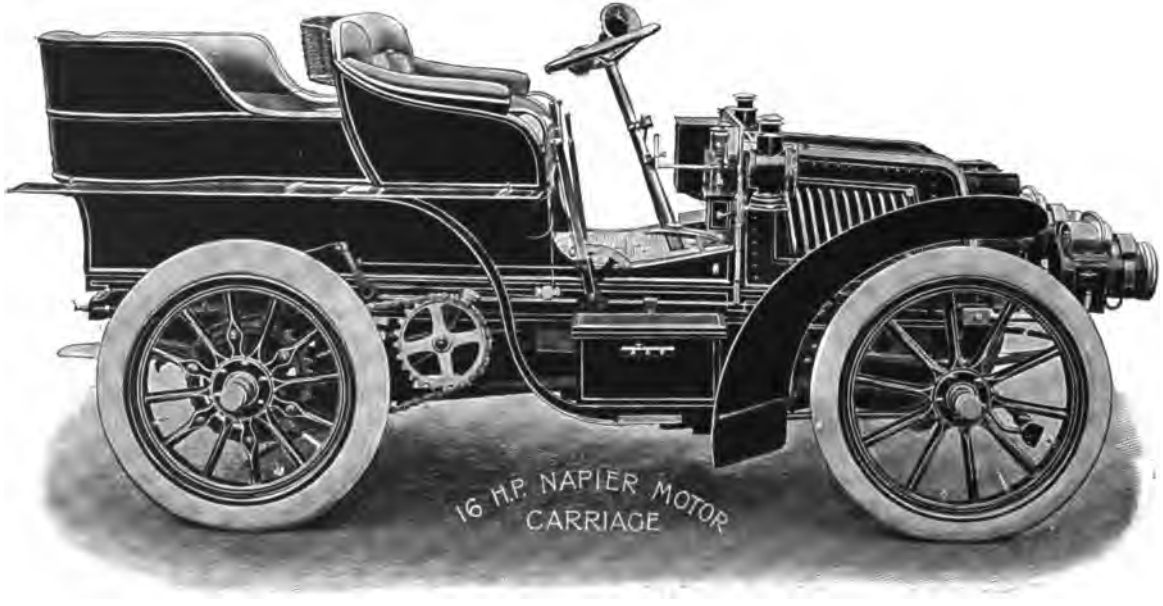
In their main features these carriages belong to the standard type; that is to say, they have vertical engines placed in front, crank shaft lying lengthways of the car, cone clutch, variable-speed gear of the sliding-wheel type, and a transverse compensating-gear shaft driven by bevel gearing and coupled to the rear wheels by chain gearing. They present, however, numerous improvements in detail, which have been carefully worked out, and have been to some extent copied by other makers, and the builders have attained a very high reputation for careful workmanship and great strength combined with lightness.

The Napier firm makes cars of five different nominal powers, *i.e.*, nine, ten, sixteen, twenty, and forty horse-power, the engines of which give off respectively twelve, fourteen, twenty-four, thirty, and sixty-five horse-power, when tested on the friction-brake dynamometer. The nine horse-power has a two-cylinder engine, all the other sizes have four cylinders.

Engines.—The cast-iron cylinders are forced by hydraulic pressure into a casing of aluminium; this is divided in the plane of the crank shaft, and the lower part is removable; doorways are provided in the upper part for

access to the cams which lift the exhaust valves. The cam shaft is enclosed in the engine casing, but extends through it at the rear to carry the contact breaker which is on the dashboard facing the driver. The cylinder heads are fitted on the cylinders by means of ground joints, and are secured by long bolts which pass down to the lower part of the engine casing. The inlet-valve boxes are each held down by a single bolt, so that by unscrewing this and slackening two others, which secure the induction pipe, they may be removed to allow of access to the valves. The inlet valves are a special feature in that three valves are combined in one, in order to give increased area of opening for the same lift.

Regulating.—The system of regulating the speed of the engines is also noteworthy. The regulation is effected entirely by throttling the supply of explosive mixture. For this purpose a centrifugal governor is mounted on the forward end of the crank shaft just outside the engine casing; the governor is linked to the spindle of a throttle valve, which takes the form of a hollow cylinder or ring fitted to slide in a barrel bored out in one end of the mixing chamber of the carburetter. The float chamber is at one side of the mixing chamber, and the supply pipe from it leads into the jet pipe which stands up in the middle of the bottom of the mixing chamber The induction pipe leading to the inlet valves is bolted on to the mixing chamber opposite a square opening in the barrel, while at the other end are the air inlets. Upon the suction strokes of the engines air is drawn in, carburised by the petrol, drawn up through the jet pipe, and passes on through the hollow cylinder, then out through the square opening in the barrel to the induction pipe. When the ring is pushed into the barrel as far as it will go, the square opening in the side of the latter is quite unobstructed, and the maximum supply of mixture passes to the engines. As the ring is moved out towards the end of the barrel, its edge gradually covers the opening and so


16 H.P. NAPIER MOTOR
CARRIAGE

restricts the passage, until, when at the end of its movement, it closes it entirely. The governor which imparts this movement to the ring may be thrown out of action by a pedal, when it is required to accelerate the speed of the engines beyond the normal speed for which the governor is set. From the top of the mixing chamber, immediately over the jet pipe, an air pipe proceeds to the dashboard, where its end is fitted with a cap to regulate the supply of air passing along it. Another pipe leads from the end of the mixing chamber, opposite to the induction pipe, to a shell which loosely encircles one of the exhaust pipes, so that the air drawn through it is heated by contact with the exhaust pipe.

Cooling.—The cylinders are cooled by water circulated in the space between them and the engine casing; the cylinder heads are also water jacketed. The radiator for cooling the water is at the front of the car; the water tank behind; the circulating pump is driven by friction from the fly-wheel rim, and a gauge on the dashboard serves to indicate whether it is working properly.

Silencer.—The exhaust passes out through a double silencer; it first enters a barrel extending lengthways and is then led to another extending across the back of the frame.

Gearing.—The wheels of the variable-speed gear are made of ample proportions, of steel, and hardened after the teeth are cut; they are finally worked with emery and oil to bring the teeth to good working faces. Four speeds forward and a reverse are provided for. The compensating gear is enclosed in the gear box. The transverse shaft is placed forward of the speed gear.

The gear box, made of aluminium, has a doorway on top fitted with a sliding cover, which is of greater width at one end than at the other in order that after a short sliding movement in its seat it may be lifted away bodily.

Frames.—The frames are of channel steel, except in the ten-horse-power car where ash timber strengthened by steel flitch plates is used. The engine and gearing are supported

on an underframe of angle steel. The engine, etc., are cased in entirely below by aluminium sheeting.

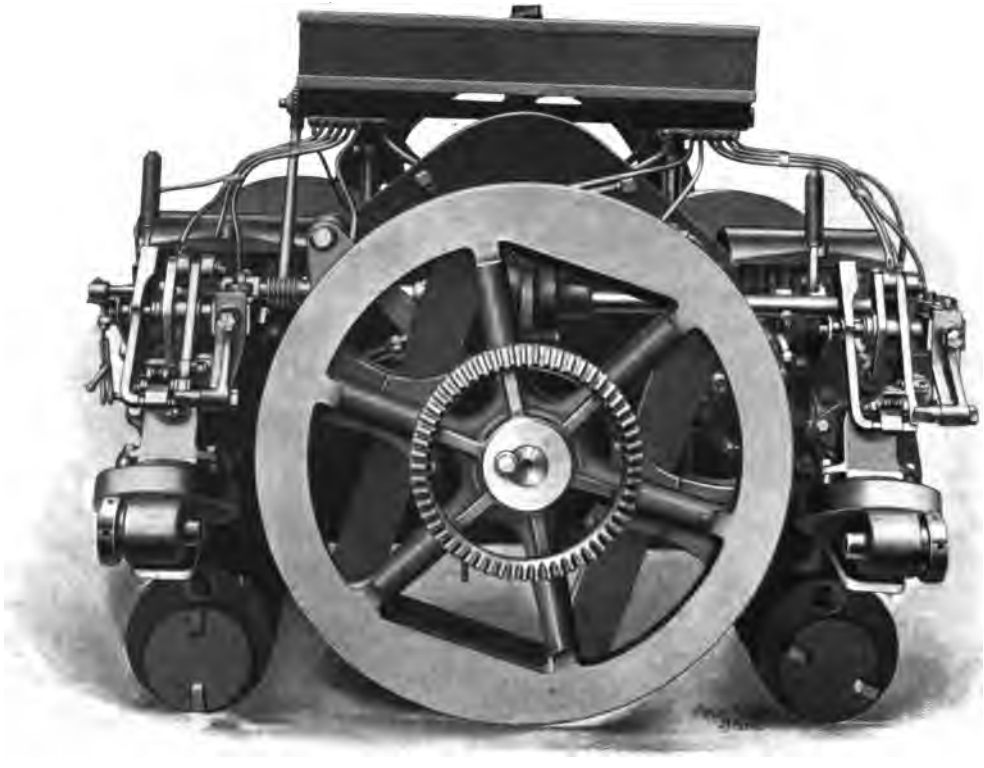
The wheels are of the artillery pattern, mounted on parallel axles. The steering is by wheel acting through worm and sector. Two sets of band brakes are provided, one actuated by hand, the other by pedal; both sets are coupled to the clutch-actuating mechanism, so that the engine is disconnected when either of them is applied. The brakes on the compensating-gear shaft are provided with water-cooling arrangements, to which the water may be supplied from a tap on the dashboard.

The first car turned out by the Napier firm did remarkably well in the Automobile Club's 1000 miles test in 1900, although it had been completed only a few days before the beginning of the trial. Since then their productions have always been well to the front both at trials and in the estimation of automobilists, and recently they gained the distinction of having made the winning car in the competition for the Gordon-Bennett cup.

The Lanchester Car

The carriages built by the Lanchester Engine Company are marked by features of great originality and ingenuity. Motor, cooling system, valve gear and governor, ignition, carburetter, transmission and speed gearing, lubrication, suspension of vehicle, and many other points have all received the most careful thought and exhibit a marked degree of inventive skill. As to general arrangement, we may say that the motor is mounted in the body of the car about midway between the axles, and that it drives the rear axle by longitudinal shafts, and worm and worm-wheel gearing.

Engine. — The engine has two horizontal cylinders, placed with their axes in line and transverse to the car, and two crank shafts, each with a fly wheel, mounted in



THE LANCHESTER ENGINE

bearings one above and the other below the axes of the cylinders, and geared together by means of a helical wheel on each, so that they rotate uniformly but in opposite directions. Each piston is connected by one set of connecting rods to one crank, and by another set to the other crank. This construction ensures the balancing of the explosive forces, of the inertia of the reciprocating parts, and of the angular thrusts.

Valve Gear and Governing.—Both inlet and outlet valves are positively actuated by levers and cams on the half-speed shaft, which is driven by screw gearing from one of the crank shafts. The inlet-valve levers act through a hit-and-miss arrangement controlled by an inertia governor which serves to cut out the charge when the speed rises above the normal. For this purpose the valve lever has, pivoted on its lower end, a balanced block or tumbler fitted with a blade; this is adapted to catch under a knife edge on the valve stem, and thus to transmit to it the inward movement of the lever. A weighted governor lever is pivoted, at its centre of gravity, in the axis of the valve lever, and engages, by means of a tooth at its lower end, with a fork formed on the tumbler; this lever is also formed with a projecting pin, which is held against the side of the valve lever by the action of the spring. As long as the speed of the motor is at, or below, the normal, the governor lever and tumbler are practically one with the valve lever, and rock to and fro with it, under the action of the cam and retracting spring, and the tumbler blade at each inward stroke engages with the valve stem, and pushes it in to open the valve and admit a charge to the cylinder. When the speed rises above the normal, the cam pushes in the valve lever with increased rapidity; the inertia of the governor lever prevents it from moving so quickly and it lags behind, assuming an angular position in relation to the valve lever; the tooth at its lower end then tilts the tumbler on its pivot, the tumbler blade therefore fails to catch in the notch in the valve stem, which consequently is not pushed in, so that

the charge is not admitted to the cylinder. This continues for each movement of the valve lever until the speed falls to, or below, the normal, when the governor lever is again able to advance at the same speed as the valve lever, and thus to keep the tumbler in the engaging position. To enable the speed of the motor to be increased when desired, a lever actuated from the driver's seat is adapted to control a spring, the increased tension of which prevents the governor blade from disengaging until a higher speed is reached.

The pivoting of the governor lever and tumbler upon their centres of gravity prevents the movement of the car from influencing the action of the governor.

Ignition.—The ignition is on the low-tension magneto-electric system. Two bar magnets are fixed across one of the fly wheels; these revolve round a stationary armature, which however can be rocked about the axis of the crank shaft to vary the period of ignition. Current is conveyed from the armature by insulated steel bars, no conducting wires being employed. The ignition plug is contrived so that it may be inserted and removed in a remarkably simple and expeditious manner; it is merely pushed into the opening in the combustion chamber and then locked by a partial turn of a handle, somewhat in the manner of a gun breech action; when drawn home into place the plug forms a gas-tight joint, without the necessity for packing. When pushed home the handle lies beyond the vertical, so that the jolting of the car has no tendency to shake it loose. Within the plug is an insulated metal bush clamped between groups of mica washers by a gland screwed into the outer end of the plug. Through the centre of the bush passes a metal wire, the end of which, inside the combustion chamber, is bent at right angles, so that when turned it makes contact with an anvil in the form of a wing projecting from the plug. The outer end of the wire is split to receive the ignition spring, which is a flat strip of thin steel with pointed ends; one of the ends

is perforated to engage with a detent pin, the other end lies in the path of a wiper or "tweaker" on the cam shaft. The detent pin is carried in a bracket, mounted on the ignition plug outside the locking handle; it is insulated and formed with a downwardly-projecting tail adapted to be engaged by the forked end of a switch clip pivoted on the insulated steel bar which conveys the current from the magneto machine. When this switch is engaged with the detent pin it will be understood that there is electrical connection from the magneto to the ignition spring and to the wire passing into the combustion chamber, the bent end of which is separated by a narrow gap from the wing on the plug. A circuit is completed when the wiper on the cam shaft comes round into contact with the ignition spring, the pressure of the wiper on the spring causes the wire to turn in the insulated bush and to bring its bent end into contact with the anvil, so that a circuit is also completed here. When the wiper leaves the spring the first circuit is broken and the whole current passes through the second; this is but for a moment, as directly the wiper liberates the ignition spring the spring recoils beyond its normal position and thus separates the contacts inside the combustion chamber; the rupture of the circuit is very sudden and is accompanied by a good spark. In order to regulate the space between the sparking contacts a toothed collar is formed on the end of the plug to gear with a worm carried in the bracket of the detent pin; the rotation of this worm, by hand, causes the bracket to turn on the plug, and by means of the detent and ignition spring this movement is transmitted to the wire.

Carburetter.—The carburetter is of the surface type, and consists of a pot fitted in the top of a cylindrical petrol tank which extends across between the sides of the frame in front of the motor. The pot is provided with a lid, and in its bottom are a number of perforations through which wicks hung in the pot descend into the tank. The wicks carry up the petrol and expose it over a large

surface to the current of air passed through the pot. This carburetter is found to give very satisfactory results.

THE LANCHESTER STANDARD TOURING CAR.

Cooling.—The cylinders, which carry radiating webs, are partly enclosed by sheet-steel jackets, and are cooled by currents of air drawn through the webs by centrifugal

fans driven by friction gearing from one of the fly wheels.

Lubrication.—All the important bearings about the motor are lubricated through a system of connecting pipes from a tank mounted above it which has an automatic feed driven by the motor.

Transmission and Speed Gearing.—The helical wheel on the lower shaft of the motor engages on its lower side with a wheel on a hollow shaft mounted in the gear box. Through the hollow driving shaft passes a driven shaft; this conveys the motion to a worm in gear with a worm wheel, which encloses the compensating gear on the rear axles. The driving and driven shafts are coupled together for the high speed, on which most of the running is done, by means of a friction clutch. The sliding part of this clutch is on the driven shaft, and when it is moved sufficiently far back its rear face engages with a fixed brake ring. The clutch-actuating lever, therefore, when moved one way, puts the high speed in action, and when moved the other way applies the brake. Lower speeds and reversing are obtained by the aid of epicyclic-gear trains, which are set in action by brakes. The low-gear and reverse-train brakes are controlled by the same lever; when this is in its central position both brakes are off and both trains are idle; it is moved forward to produce forward motion of the car, and backward to produce backward motion. The third epicyclic-gear train, called the "compound gear," is combined with the low-gear train, and gives an intermediate speed forward.

Suspension.—At each end of the car are two leaf springs secured with about one half of each projecting beyond the body. The outer end of each spring extends into an opening in a suspension bracket, carried by the frame containing the axles, and rests upon a roller mounted therein. The bracket extends above and below the axle, the opening for the spring being below, and the upper end of each is coupled to the car body by means of a link pivoted at the

ends. This construction gives great elasticity, and makes riding comfortable even over very rough roads

The use of worm gearing for the main power transmission has been much criticised on the score of want of efficiency. There is no doubt that in the ordinary case of a worm with one thread gearing with a wheel of many teeth there is a considerable loss of power in transmission. But it does not follow that worm gearing cannot be so proportioned and constructed as to reduce the loss to within reasonable limits, and this the Lanchester firm seem to have succeeded in doing, for the consumption of petrol is not in general at all excessive, and recently a car carrying two persons, driven by an amateur, covered a distance of 101 miles with four gallons of petrol. The exceedingly small wear of the worms also tends to show that the frictional losses cannot be exceptionally great.

The Albion Cars

In these cars the engine is placed in the body of the vehicle between the front seat and the rear axle.

Engine.—The motor is a horizontal, two-cylinder balanced engine, with the cylinders placed one on each side of the crank shaft, which has the cranks set at 180 degrees apart, and lies across the car. The cylinders are four inches diameter, and five inches stroke, and adapted to give off eight brake horse-power at the normal speed of 700 revolutions per minute; they are water-jacketed together with the exhaust-valve chambers, which are formed integrally with them. The inlet-valve chambers are formed on the cylinder covers, which are not jacketed. The valves are readily accessible, and may be removed without disturbing the pipes.

Governing.—The governor is enclosed in the crank chamber; it acts upon the exhaust valves, and is fitted with an accelerator permitting a range of speed from

200 to 1000 revolutions per minute. The opening of the induction valves, and hence the supply of gas to the engine, may also be regulated by means of a lever acting upon the springs of these valves. A single float-feed carburetter supplies both cylinders.

THE ALBION DOCTOR'S CAR.

Ignition.—The ignition, on the low-tension electric system, is effected by a magneto machine on the engine shaft.

Gearing.—The gear box and crank chamber are formed in one casting of aluminium, which is mounted in a steel frame, in which the road wheels also are supported, the carriage body being entirely independent and easily removable. The first-motion shaft lies directly below the engine shaft, from which it is driven by a pinion of raw hide fixed

to one member of the cone friction clutch. The second-motion shaft drives, by a single chain, a short shaft, mounted in an extension of the compensating gear box, which transmits its motion to the live rear axle by toothed gearing. The compensating gear box may be turned on the axle to regulate the tension of the chain. The change wheels for forward running are constantly in mesh, but the wheels on the second-motion shaft are loose, and are locked to it as desired by claw clutches. In order to avoid jar and noise in throwing the clutches into gear they are arranged to act first as friction clutches, the sliding member of each clutch being fitted with radial plungers pressed outward by springs into contact with an annular flange on the other member. The gearing is proportioned to give two speeds forward, thirteen and five miles per hour, and one backward, four miles per hour, with the engine running at the normal speed.

Steering.—The front axle is pivoted in the usual way, and the steering is effected by a tiller or lever; rubber buffers are interposed in the connections to absorb shocks.

Brakes.—The brake on the second-motion shaft consists of a pair of segmental brake blocks adapted to resist rotation in either direction; the brakes for the road wheels act upon the tyres, which are of solid rubber; the wheels are of wood.

The petrol tank is in the front of the car, as is also the radiator; the water tank is at the back, and the circulating pump is driven by an endless band.

The mechanism of this car is of simple and straightforward design, and, as it is all above the level of the axles, and the wheels are of large diameter, the working parts are well removed from the dirt and dust of the road, a most important consideration in an all-weather car. In regard to accessibility of the engine, of course no other construction can equal the common arrangement with the engine in front of the car, still the Albion Motor Car Company have contrived matters so that it is by no means difficult of

access. These cars have a good reputation for reliability and hill-climbing power. A privately-owned Albion car, at the Glasgow trials in 1901, out of a possible total of 300 marks, lost six on the first day, while on each of the four succeeding days of the trial it gained full marks. In addition to the Doctor's car shown in the illustration, the Albion is sent out as a business-man's car, a sporting dogcart and a tonneau, the two last to seat four.

The Humber Cars

In their main lines the cars of the Humber Company follow standard practice; they have vertical engines in front, sliding-wheel variable-speed gearing, and bevel-wheel drive to live rear axle. The eight horse-power car has a two-cylinder, and the twelve horse-power a four-cylinder engine.

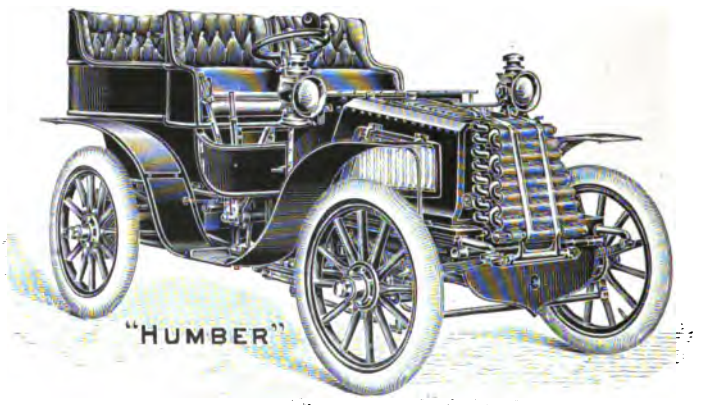
The cylinders are formed in pairs with their heads and jackets, which extend round the exhaust-valve boxes, cast on. The governor acts on the exhaust valves by a hit-and-miss arrangement, which prevents one or more of the valves from being opened when the speed rises above the normal, and a throttle valve controlled by hand is fitted in the inlet pipe. Both tube and electric ignition are fitted. The cooling water is circulated by a semi-rotary pump worked by a crank on the cam shaft; the water tank is in front of the dashboard and the radiator in front of the car; it is hinged at its lower edge so that it may be turned downwards to afford access to the engine.

The frame is composed of tubes; an underframe, which supports the gear box, may be removed readily when it is required to drop the gear box for repair of any of the parts.

The first-motion shaft of the speed gear is coupled by a universal and sliding joint to the male member of the friction clutch, which is composed of aluminium and is

normally pressed into engagement with the female cone formed in the fly wheel by a spring. The leather band which surrounds it is supported at four points by springs, so that when disengaged it protrudes at these points, and accordingly comes into action gradually when engaged.

In the gear box the first-motion shaft carries a sleeve capable of sliding on it; this carries four spur wheels and may be moved to bring any one of the wheels into mesh with a corresponding wheel on the second-motion shaft or with an intermediate reversing pinion. The movements



THE HUMBER CAR.

of the sleeve for speed changing and reversing are produced by a single lever; another handle is provided by which the eccentric spindle of the reversing pinion may be turned to take it out of engagement with the wheel on the second-motion shaft when desired.

The second-motion shaft drives, through universal and sliding couplings, a short shaft which carries a bevel pinion; this gears with a wheel secured on the case of the compensating gear which is mounted on the inner ends of the two halves of the axle which at their outer ends have the road wheels fixed to them; a spur wheel fixed on the inner

end of each axle gears with a pinion mounted in the case, and the pinion of one wheel is geared to that of the other; ball bearings are provided to take the thrusts of the bevel wheels. The band brakes on the rear wheels are worked by a steel-wire cord, which passes over a pulley on the brake lever and through a guide tube extending across the car.

The steering wheel is formed with but one arm connecting its rim to its centre, in order that the ignition and throttle levers mounted upon it may be more readily accessible; it is mounted at the head of an inclined steering pillar, the angle of which may be changed, and acts through a worm and segmental wheel.

The dashboard is secured to an aluminium bridge which extends across the frame.

The silencer is at the back of the car, the pipe leading out of it extends transversely, and is perforated so that the escaping gas tends to prevent the dust from rising to the car.

The Brooke Car

The Brooke car is driven by a three-cylinder vertical engine, and the transmission to the road wheels is effected by chain gearing throughout. The engine is placed under a bonnet in front of the car with the crank shaft, on which the cranks are set at equal angles apart, lying transversely. The crank shaft drives the first-motion shaft of the variable-speed gearing by means of a Renold's chain, and the second-motion shaft, which carries the compensating gear, drives the road wheels by a chain on each side of the car. The first and second-motion shafts are coupled, for forward driving, by three sets of chain gearing of different ratios; the chain wheels on the first-motion shaft are fixed to it, those on the second-motion shaft are loose, but any one of them may be fixed at will by means of claw clutches. The reverse motion is obtained by bringing a pair of inter-

mediate wheels into gear with spur wheels fixed on the shafts. The movement of the clutches and of the intermediate wheels is obtained by means of cams mounted on a shaft which is rotated by a hand lever acting through a toothed segment and pinion.

Another interesting feature in these cars is the method of governing by the variation in pressure of the exhaust gases. As the speed of the engine increases, the volume of gas discharged from the engine in a given time also increases; an increase of pressure is thereby produced which is utilised to control a throttle valve in the inlet pipe. For this purpose a chamber fitted with a piston is placed in communication with the exhaust pipe; with a rise of pressure in the chamber the piston is pushed outwards in opposition to a spring and carries a valve across a valve chamber in the inlet pipe; as the pressure falls the spring presses the piston and valve back to the normal position. The cylinder cooling water is circulated by gravity.

The Argyll Cars

These cars belong to the type with a single-cylinder vertical engine under a bonnet in front driving a live rear axle by a longitudinal shaft and bevel wheels. Simms engines with Simms-Bosch magneto ignition, or those of the Motor Manufacturing Company with high-tension electric ignition, are fitted as preferred; the builders make all the rest of the car at their own works. The cylinder cooling water passes by natural circulation through a cooler which forms the front and sides of the bonnet and is composed of upper and lower tanks of horse-shoe shape united by a series of rows of vertical radiating pipes.

The variable-speed gear is of special design arranged to give a direct drive at the high speed. The first-motion shaft takes the form of a hollow sleeve connected to the clutch by a flexible coupling, and carries a spur wheel

which is permanently in mesh with a wheel on the second-motion shaft; another wheel on this shaft is likewise always in mesh with a wheel on a third shaft which fits in the hollow first-motion shaft and is connected by a universal coupling to the longitudinal shaft which drives the rear axle. The third shaft carries a double-faced positive clutch, which may be moved one way to lock the loose wheel, or the other to lock the wheel on the first-motion

THE ARGYLL CAR.

shaft; in the first case the power is transmitted through the second-motion shaft and the intermediate speed is obtained; in the second, the third shaft is driven directly, and the wheels run idle. For the low speed a pinion on the second-motion shaft is slid endways into gear with a wheel mounted on the clutch. The clutch and pinion are slid by means of rock shafts extending across the gear box and worked by cams on the spindle of the gear-changing lever. For reversing, a pinion mounted

eccentrically in the upper part of the gear box is turned down to engage the low-speed wheel and pinion.

The eight-horse-power car with tonneau body weighs about eleven hundredweights. The sporting car, also of eight horse-power, weighs under nine hundredweights. It has a wicker-work body, and although more particularly designed for hill-climbing powers, is capable of a speed of thirty-five miles per hour on the level.

The Turrell Light Car

In its general appearance this car resembles the standard type, but the bonnet in front covers only the petrol and water tanks, the engine being mounted under the body of the car. The engine, a seven horse-power horizontal, running at 750 revolutions per minute, has two cylinders placed fore and aft of a two-throw crank shaft having opposed cranks, which lies across the frame. The axes of the two cylinders are kept in line so that it has been necessary to set the connecting rods one to the right and the other to the left of the cylinder axis. The exhaust valves are worked by a cam shaft lying at right angles to the crank shaft, and driven from it by helical gearing. In order to reduce compression in starting the engine, the cam shaft is movable endways in its bearings to bring into action subsidiary cams, which do not commence to close the exhaust valves until half stroke. The ignition is on the high-tension electric system with the circuit insulated throughout, and the sparks are produced between two platinum terminals. A Longuemare carburetter is used. The engine and gear box are suspended on opposite sides of the frame from cross girders. The engine shaft drives the first-motion shaft of the variable-speed gear by a cone friction clutch and a flexible coupling. The second-motion shaft carries the compensating gear and two chain wheels from which the two halves of the divided rear axle are driven by separate chains. The variable-speed gear presents the feature of maintaining the wheels con-

stantly in mesh, so that there is no sliding in and out of gear. The wheels on the first-motion shaft are keyed in place, those on the second motion ride loose, but each is fitted with a pivoted key pressed against the shaft by a spring plunger, and the shaft itself is made with a single keyseat with rounded ends, and is movable endways to bring the seat opposite any one of the wheels, whereupon the key is pressed down into it and couples that wheel to the shaft. The end of the shaft is squared to work through a sleeve which carries the compensating gear. A stirrup handle projecting from the footboard may be used to start the engine from the seat.

Notes on Certain Other Cars

The Motor Manufacturing Company, whose cars have become well known all over England, now build in three sizes, eight, ten and twenty horse-power, on the standard lines. The eight horse-power engine has one, the ten horse-power two, and the twenty horse-power four cylinders. The engines are governed by means of a throttle valve in the inlet pipe, and a noteworthy point is that this valve is arranged to admit atmospheric air for the purpose of cooling the cylinder, when the gas supply is completely cut off.

Both tube and electric ignition are fitted to the larger sizes of cars; electric only to the eight horse-power. An electric self-starting device is applied. The change-speed gear is arranged to have the wheels permanently in mesh; those on one shaft are loose, and the shaft is movable endways to bring a key formed on its surface into engagement with a slot in the eye of the wheel to be thrown into action.

The Brush Electrical Engineering Company have this year commenced building petrol cars, and are turning out well-designed and built vehicles in three sizes, eight, twelve and sixteen horse-power, the engines of which develop on the brake twelve, fourteen and twenty-four

horse-power respectively. In general lines these cars follow the standard type. The eight horse-power has one pair and the other sizes two pairs of engines. The cylinders are cast in pairs integrally with their jackets and ends. The crank chamber is divided in the plane of the crank shaft, and the cylinders are bolted to the upper half; the lower half in the four-cylinder engines is made in two sections, one for each pair. The inlet valves are in the centre of the cylinder ends and the exhaust valves at the sides; the covers of each pair of valve boxes are held down by a single bolt. The cam shaft is enclosed in the crank chamber, and is geared to the crank shaft by helical toothed wheels; that on the cam shaft carrying the governor which controls a throttle valve in the inlet pipe. A hand-controlled valve is provided in addition. The spray carburetter has two jets and one float feed. Either tube, or electric ignition, or both, are fitted, and, in the case of electric ignition, the contact maker, driven by chain gearing from the cam shaft, is placed on the dashboard. The cooling water is circulated by a pump of the Root's blower type, fixed to the crank chamber and driven by toothed gearing.

THE NEW ORLEANS fourteen horse-power carriage has an engine with four cylinders, each separate and mounted on a single crank chamber. The change-speed lever is arranged similarly to that described in connection with the Daimler cars. The engine is governed by a throttle valve in the inlet pipe.

The same firm also build eight and nine horse-power cars, and a three-and-a-half horse-power voiturette. The voiturette has a vertical engine in front and belt transmission to a countershaft with two pulleys, one idle and the other connected by gearing of different ratios to the compensating gear box on the live rear axle.

In the engine of the MILNE'S carriages the inlet valves as well as the exhaust valves are worked by cams, and the ignition is on the low-tension electric system, the current being provided by a Simms-Bosch magneto

machine; the igniter of any one cylinder of a group may be cut out for testing. No provision is made for varying the time of ignition. Instead of the usual radiator, the cylinder jacket water is passed into a tank in the front of the carriage; this is traversed from front to back by a large number of small tubes through which air is drawn by means of a fan worked by the engine.

The MAUDSLAY car is distinguished by the employment of a three-cylinder engine; in other respects it

THE MAUDSLAY CAR.

follows the standard type in its leading features. The frame, however, is made of rectangular steel tubing, with a core of ash timber; and barrel pumps, driven by worm gearing, are used to circulate the cylinder-cooling water. There are besides numerous other improvements in detail. The illustration shows a twenty horse-power car with an omnibus body; the glazed top may be removed when desired, to form a wagonette.

The PARR car has, like the Brooke, a chain gear transmission throughout, but in this case the second-motion shaft drives a live rear axle.

In the SWIFT car (four-and-a-half horse-power) the

connection between the vertical engine in the front and the live rear axle is effected by a longitudinal shaft, but this instead of being coupled directly to the engine shaft is driven from it, and at a lower speed, by spur wheels. At the rear end this shaft carries two loose bevel wheels, which are always in mesh with two bevel wheels of different sizes secured to the rear axle. Either of the loose wheels may be fixed to the shaft by means of a clutch placed between them; two speeds are thus provided for. Instead of a compensating gear, both road wheels are driven by free-wheel clutches, so that when travelling in a curve the outer wheel is free to overrun the axle. The longitudinal shaft is provided with universal joints, and its driving wheel is coupled to it by a friction clutch.

The EASTMEAD-BIGGS car has a longitudinal coupling shaft from the engine in front to the rear live axle, which it drives by worm gearing. The lower frame, in which the engine and speed gear are mounted, consists mainly of two longitudinal members fixed at one end directly to the front axle, and supported at the other end on trunnions. The trunnions are formed on the box which encloses the worm and compensating gears, and are in the axis of the longitudinal shaft. By this arrangement the rear axle is free to tilt about the axis of the shaft without affecting the gearing. This firm has been making cars in which the engines were controlled by regulating the lift of the inlet valves; their more recent practice, however, is to use a throttle valve in the inlet pipe.

The WILSON & PILCHER eight-horse-power car is driven by a four-cylinder horizontal engine, having the cylinders placed two on each side of a crank shaft, which lies lengthways in the frame. The crank shaft is coupled by a friction clutch to a longitudinal shaft, which drives the rear live axle by bevel wheels. Two sets of epicyclic gearing are provided to give four speeds; at the high speed these gears are locked and the transmission is

direct; the reverse is obtained by shifting bevel wheels.

The JAMES & BROWN car has a two-cylinder horizontal engine with the cylinders side by side and working on cranks at the ends of a transverse shaft with a fly wheel in the middle. The crank shaft drives, by spur gearing, a first-motion shaft which is geared by a sliding-wheel change gear to a second-motion shaft. The second-motion shaft is coupled to the rear wheels by chains. The friction clutch is applied to the driven spur wheel on the first-motion shaft.

The PICK car, as shown at the Crystal Palace in Febuary 1902, was driven by a two-cylinder horizontal balanced engine placed in front, with the crank shaft lying across the car. A countershaft placed behind the rear axle was driven from the engine by belts and carried two loose wheels, one in gear directly with a toothed wheel on one end of the compensating-gear box, and the other with a chain wheel, on the opposite end of the box, by means of a chain. Thus, by the operation of a clutch placed between the two loose wheels, the car could be driven forwards or backwards. Two speeds were obtained by using duplicate sets of belt gears between the engine and the countershaft, both sets being provided with loose pulleys.

The GAINSBOROUGH car (sixteen horse-power) is propelled by a horizontal engine mounted in front under a bonnet. The engine has two double-ended cylinders, in each of which works a double-ended piston; the explosions take place alternately on opposite sides of the pistons, so that the engine is to all intents and purposes a four-cylinder engine. The cylinders are arranged lengthways in the car, and the pistons are provided at mid-length with pins which work through slots in the cylinders, and are coupled by the connecting rods to the crank shaft. This lies across the car, and is geared by a chain to a countershaft, from which the rear wheels are driven by other chains. The countershaft is fitted with a compensating

gear and with a speed-reducing gear, and the power may be transmitted direct or through that gear. The car is fitted with a convertible top, and admits of being changed very quickly from a tonneau to a closed brougham; the top when closed slides down into a case behind the front seat.

The engine of the LUCAS car has a double-ended cylinder and two pistons which work two separate crank shafts connected by a transverse shaft and bevel gearing (as in the Bardon car), but it is adapted to work on the two-stroke cycle; that is to say, to have a working stroke for every revolution of the crank shaft. At one end of the cylinder is an inlet port, at the other an exhaust port, both without valves; these are opened and closed, one by one piston, and the other by the other piston. During the compression stroke, when the pistons are moving towards each other, air is drawn into the crank chambers and the charge already between the pistons is compressed; then ignition takes place, followed by the working stroke; towards the end of this the ports are uncovered, the exhaust gases rush out through one, and the air compressed in the crank chambers enters through the other, taking up the charge of petrol on the way. The petrol is fed through a needle valve acted upon by a diaphragm exposed to the suction of the engine. The engine will run either way; with petrol it gives off eight and with kerosene nine horse-power.

The BEAUFORT car (six horse power) has a belt transmission from the crank shaft of a vertical engine in the front to a countershaft which is connected by spur gearing to the carrier wheel of the compensating gear on the rear live axle. The pulley on the crank shaft is made wide to allow of the belt being shifted on to any one of three pulleys placed side by side on the countershaft; the middle pulley is an idle pulley; the two outer pulleys have secured to them toothed pinions of different sizes which gear with corresponding wheels on the compensating gear.

Thus by shifting the belt one of the two speeds may be employed, or the transmission may be arrested. Another small car, the VULCAN VOITURETTE, has a similar system of transmission. The radiator in this car is combined with the bonnet in the form of hollow louvres.

The MABLEY car is of a quite exceptional shape; as will be seen from the illustration, it has on opposite sides two seats, each half the length of the car, and runs on four wheels, one at each end and two in the middle. Both end wheels are steering wheels, and are operated simultane-

THE MABLEY CAR.

ously. The middle wheels are fixed to the axle, which is driven through belt and chain gearing from a two-and-three-quarters horse-power engine, with a water cooled head, mounted together with the tank and radiator in front. The speed is controlled by varying the time of ignition. The extreme dimensions of this quaint little car are eight and a half feet by four feet, and its weight is four and a half hundredweights.

In the MEREDITH car the variable speeds are obtained by means of three pairs of bevel wheels of different ratios used to connect a longitudinal shaft to a transverse shaft which is in line with, and coupled by means of a clutch to

the shaft of a two-cylinder engine placed at the right-hand forward corner of the frame, under a bonnet. The bevel wheels on the transverse shaft may be moved endways to bring any one of them into gear with the corresponding wheel on the longitudinal shaft. The longitudinal shaft drives the rear axle by bevel gearing.

There are many other cars, the Belsize, Capel, Century, Dennis, Progress and Star, for instance, which deserve mention as having given good results in actual working, but which do not differ so much from the standard type as to call for description here.

Roots and Venables' Carriage worked by Heavy Oil

The difficulties which arise in vaporising kerosene, or ordinary lamp petroleum, in the engines of motor cars appear to have been overcome by Messrs Roots and Venables, who, for some years, have been building carriages, the engines of which are adapted for consuming heavy oil. Some of these carriages are at work in England, but the greater number are sent abroad to tropical countries, where petrol is found to volatilise too rapidly to be safe. The plan adopted for vaporising the oil is briefly the following: a reciprocating plunger feeds the oil in small quantities, and at the required intervals, into the automatic burner, and into the vaporiser, where it is caught and converted into vapour by a current of hot air, set up by the induction stroke of the engine, and carried into the cylinder. A single burner serves to heat the vaporiser and the platinum tube used for igniting the charge in the cylinder. The action of the reciprocating plunger is controlled by the governor. The mixture thus supplied requires diluting, so additional air is admitted to the cylinder by an air valve provided in addition to the ordinary inlet valve. For starting, the vaporiser and ignition tube are heated by a blow lamp,

This firm build a light carriage, to seat two persons, fitted with a single-cylinder horizontal engine arranged under the body with its crankshaft forward of the cylinder. The half-speed shaft, for working the exhaust valve, is driven by chain gearing, and both crank shaft and half-speed shaft are connected to the rear axle by chain gears, either of which may be thrown into operation by means of clutches; in this way two speeds are obtained.

A novel arrangement for cooling the circulating water consists of a large diameter coil inside which runs the fly wheel, so that the air currents set up by its rotation flow round the coil. In addition to this car the makers build a four-and-a-half horse-power car with the motor in front, under a bonnet, and a seven horse-power car with tonneau body and pneumatic tyres. The smaller cars are fitted with solid rubber tyres.

CHAPTER XIII

PETROL CARRIAGES OF TO-DAY—CONTINENTAL AND AMERICAN

The Panhard & Levassor Cars

The early connection of this celebrated firm with the petrol motor car has been dealt with in a preceding chapter, and it has been explained that the arrangement of motor and gearing which they adopted is now so generally used by other makers as to have become the standard type. This being so, little remains to be done beyond pointing out some recent changes in their practice. The engines are governed by a throttle valve, acting on the mixture supply, which is in the form of a movable perforated cylinder enclosing the carburetter nozzle. The carburetter is modified so as to dispense with the usual double levers above the float, and has two air supplies, one of heated air, taken in near the exhaust pipes, and the other of air at the atmospheric temperature, which may be regulated as required. The clutch on the coupling shaft is so mounted that it is free to move vertically and sideways, and it is actuated by means of a rod passing axially through the shaft.

The "Centaure" engines of the fifty horse-power racing cars, of which so much has been heard, are remarkable for the power developed in proportion to their weight. They are four-cylinder engines, which, running at 950 revolutions

PANHARD AND LEVASSOR CAR, 1902.

per minute, give off seventy brake horse-power, and they weigh about 680 pounds, or less than ten pounds per horse-power. The cylinders are formed of forged steel, each separate and bolted to the crank chamber. The jackets are formed of thin copper, corrugated to allow them to expand and contract. The cylinder heads are separately water jacketed, and are coupled together in order to stiffen the engine.

PEUGEOT EIGHT HORSE-POWER CAR, 1902.

The crank chamber, divided horizontally in the plane of the shaft, is provided with bearings between each crank.

THE PEUGEOT CARS

The Peugeot firm, one of the pioneers in the motor-car industry, have been identified from the first with the use of horizontal engines. Now, however, they have come into line with the majority of other builders, and are making a series of cars fitted with vertical engines in front; but they still con-

tinue to make an eight horse-power car with a two-cylinder horizontal engine, placed above the rear axle. The new cars are made in five, six-and-a-half, eight and ten horse-power sizes. The five horse-power voiturette—"the Baby Peugeot"—which seats two persons, has already become a great favourite in this country; this and the six horse-power car are propelled by single-cylinder engines, which drive a live rear axle by means of a longitudinal shaft. The eight horse-power car has a two-cylinder, and the ten horse-power a four-cylinder engine, and the rear wheels are driven in the usual manner, through a sliding-wheel variable-speed gear, a transverse compensating-gear shaft and chains. These two cars have frames of wood strengthened by steel plates. The governor acts on the admission. The two and four-cylinder engines may be fitted with tube, high-tension electric, or magneto-electric ignition, or any two of them; the single cylinder engines have high-tension electric ignition only. Both the inlet and the exhaust valves are mechanically actuated, and the cylinder cooling water is used to warm the carburetter.

The De Dion-Bouton Cars

The six horse-power voiturette of this firm is on the same lines as their earlier four-and-a-half horse-power vehicle, and has the engine under the body. The new (1902) eight horse-power light car has the engine in front, under a bonnet.

The De Dion-Bouton petrol engines are very well known, and are in extensive use by other builders of motor cars and motor cycles and for other purposes (upwards of 34,000 have been built in various sizes up to eight horse-power). They are single-cylinder vertical engines, fitted with Viet float-feed spray carburetters, provided with a valve by which the degree of carburisation of the charge may be varied from zero upwards. The ignition is

DE DION-BOUTON EIGHT HORSE-POWER CAR, WITH LIMOUSINE BODY, 1902.

on the high-tension electric system, the current being supplied by dry batteries. In addition to the control by the carburetter and by the timing of the ignition, the engines of the six and eight horse-power cars are provided with means for regulating the extent of the opening of the exhaust valves, and thus, by retaining more or less of the spent charge in the cylinder, the amount of the fresh charge drawn in through the inlet valves. For this purpose a horizontal lever pivoted on a movable fulcrum is interposed between the cam and the lower end of the exhaust-valve stem. This lever has a projection which normally rests on the cam, and the lever then transmits the movement undiminished to the valve. When the fulcrum of the lever is shifted to its extreme position towards the valve stem, the projection is moved beyond the path of the cam, so that the valve stem resting upon the upper surface of the lever remains at rest, and the exhaust valve is kept closed, whereby the escape of the spent charge and the entry of a fresh one is prevented. Intermediate positions of the fulcrum correspond to varying lifts of the valve.[1] This device serves not only to allow the driver to regulate the power of the engine, but it materially lessens the noise and vibration when the car is stationary or travelling slowly; it is controlled by a small lever on the dashboard, and is also connected to the brake pedal.

A special feature of the De Dion-Bouton practice is the construction of the driving axle. The road wheels are mounted on short axles, each connected by an intermediate shaft, having a universal coupling at both ends, to the corresponding member of the compensating gear. In the voiturette, with the engine underneath, the compensating gear is driven from the second-motion shaft of the speed gear by spur gearing. In the eight horse-power car the engine shaft is connected to the first-motion shaft of the speed gear by a shaft extending along the centre of the car and provided with a universal

[1] *See* the *Automotor Journal*, Vol. vi., p. 186, for a full illustrated description.

coupling at each end, and the second-motion shaft drives the compensating gear by bevel wheels. The speed-gear box and the compensating-gear box are bolted together.[1]

The second-motion shaft carries a brake drum, against which a pair of brake blocks are pressed by means of a pedal; the band brakes on the rear wheels are worked by a hand lever at the side of the car. The wheels are of wood (the firm are now giving up the use of wheels of the bicycle type). The frames are formed of steel tubes. The steering pillar in the new cars is inclined; its upper end is steadied by a pair of vertical tubular pillars, on one of which the speed-changing handle is mounted, while the other carries the ignition lever and the carburetter lever. The cooling water is circulated through a tank, under the bonnet, and a radiator, in front of the car, by means of a centrifugal pump driven from the cam shaft by means of a short spindle with universal couplings. The petrol tank is on the dashboard and the dry battery under the driver's seat.

The vehicle shown in the illustration has a "Limousine" body, in which the left-hand front seat is hinged and may be turned up by the driver, when standing at the side of the car, to form a passage for entry to the rear seats. Siamese phaeton and tonneau bodies are also fitted.

The Delahaye Cars

Up to the year 1901 all the Delahaye cars were built with the engines behind. Now, however, the firm are falling into line with most of the other large makers, and their 1902 models have the engines under a bonnet in front of the car. They still retain the horizontal position of the engine, and, in a modified form, the belt drive from the engine to the differential shaft. The engine shaft is transverse to the car and carries a wide pulley which forms the fly wheel. The differential shaft, parallel to the engine

[1] The speed gear is of a special type adapted to give two speeds only.

shaft and to the axles, carries two driving pulleys separated by a loose pulley. A single, crossed, belt embraces any one of these pulleys and the drum on the engine shaft. One of the driving pulleys is fixed to the differential shaft, so that when the pulley is over it this shaft is driven at the highest speed. The other driving pulley is loose upon the shaft, but carries a pinion which gears into a wheel on a short, parallel, shaft fitted with two sliding wheels. Either of these wheels may be moved into gear with corresponding wheels on the differential shaft; thus when the belt is on the second pulley either the low or the intermediate speed may be obtained. Formed on the same sleeve with these wheels is a pinion which may be slid into gear with an internal wheel fixed on the differential shaft to give the reverse. The belts are controlled by an ingenious combination of pedal and hand lever mounted on the steering pillar. The pedal serves to determine whether the belt shall be on the loose pulley, to disconnect the engine, or on one of the driving pulleys, and the lever with which of the driving pulleys it shall be engaged. Another lever is provided to throw the low, intermediate, or reversing toothed wheel into action. The differential shaft drives the rear wheels by means of chains.

The eight horse-power car has a single-cylinder engine running at from 900 to 1200 revolutions per minute, and giving off from eight-and-a-half to nine horse-power on the brake. The twelve horse-power car has a two-cylinder engine running at from 950 to 1400 revolutions per minute, and giving off from thirteen-and-a-half to fourteen brake horse-power; the cylinders are placed side by side, and the pistons work on to opposed cranks. The valve box is cast on the end of the cylinder and is right in the front of the car. The ignition is on the high-tension electric system, and the period of firing may be advanced or retarded by a handle mounted on the steering pillar. This handle is also coupled to a device which shifts the exhaust-valve cam, whereby the exhaust

valve is kept open during a part of the compression stroke, to relieve the compression in starting the engine. The speed of the engine is regulated by a pedal-controlled throttle valve in the inlet pipe. The carburetter is one in which the air bubbles through a volume of petrol maintained at a constant height. It is equally serviceable for alcohol, as the air is supplied in a heated state, being drawn through a jacket formed round the crank end of the cylinder. The outer end of the cylinder and the valve box are cooled by water circulated by a centrifugal pump; this with the water tank and radiator are all in front of the car.

The Benz Cars

The first motor cars made by Carl Benz in 1885 and 1886 had the engines placed under the bodies of the cars, and this disposition became one of the distinguishing features of the productions of the Benz Company. In the 1902 models, however, while the general lines of construction and system of gearing have been retained, the engines are placed in front. In the older type, which has still a great many admirers, the engine is mounted above the rear axle with the combustion chamber directed forwards, and the crank shaft is connected by two sets of belt gearing, combined with toothed wheel speed-reducing gear, to a countershaft, extending across the car in front of the engine, from which the rear wheels are driven by chains. The mechanism is supported entirely in the body of the car.

The new model has a two-cylinder horizontal engine placed under a bonnet in the front, with its crank shaft lying across the frame. The crank shaft is connected by belt gearing to the first-motion shaft of a sliding-wheel change gear. The second-motion shaft carries the compensating gear and the chain wheels by which motion is transmitted to the road wheels. The petrol

THE BENZ THREE-AND-A-HALF HORSE-POWER CAR.

THE BENZ CAR, 1902.

flows by gravity from a tank at the rear of the car to a float-feed carburetter. In the pipe from the carburetter to the cylinder is fitted a throttle valve, controlled by a governor in the twenty horse-power car, and by hand in the smaller sizes. The valve boxes are at the sides of the cylinders, and the exhaust valves are worked by jointed levers from a cam on the half-speed shaft. The high-tension electric-ignition system is used, and a trembler coil is used for each cylinder instead of one for the two as formerly. The frame is of ash timber and steel plates, and the engine, gearing, water tank and cooler are mounted within it.

THE CANNSTADT-DAIMLER (MERCEDES) CARS

These cars are of the normal type in so far as they are driven by vertical engines placed in front and geared to the road wheels by sliding-wheel speed gearing and chains at the sides of the car. One special feature, however, which at once attracts attention is the tank for the cylinder cooling water mounted in the front of the car. This tank is traversed by a large number of small tubes, open at the ends, through which air is drawn by the action of a fan driven by the engine or formed in the fly wheel. The engine is entirely encased, so that all the air passed through the fan has to be drawn through the tubes; the cooling action thus set up in the tank enables a separate radiator to be dispensed with.

The forty horse-power Mercedes-Simplex car has attracted a good deal of attention among experts, and presents many features of interest.[1] It has a four-cylinder vertical engine with a crank shaft extending longitudinally in the frame; the cylinders are formed

[1] Mr A. C. Harmsworth is the possessor of one of these cars, which he was good enough to send for exhibition to the last Automobile Club Show. A full and illustrated description of it will be found in *The Autocar* for May 10, 1902, and succeeding numbers.

in pairs, the heads and water jackets are cast on; the inlet valves are ranged along one side and the exhaust valves along the other side; both sets of valves are positively operated by cam shafts lying under their stems. The carburetter is of the float-feed spray type, with one float chamber and jet for the four cylinders; the mixing or vaporising chamber takes the form of a horizontal tube into which the jet nozzle projects vertically; it is fitted with a throttle valve controlled by the governor, and is enclosed in a box supplied with air which has been heated by contact with the exhaust pipes. The nozzle is provided with a cap, the position of which is adjusted by a handle on the steering wheel to regulate the flow of petrol. The governor is provided with a hand control. The speed of the engine may be varied from about 200, when the throttle is closed as completely as it allows, up to 1200 revolutions per minute.

The ignition is on the low-tension magneto-electric system; the magneto has a rotating armature, the moving contacts in the combustion chambers are rocked by a system of levers from a cam shaft, and provision is made for varying the timing of the breaking of the circuit. The cylinders discharge into a single exhaust pipe in which is fitted a valve whereby the gases may be discharged directly into the air or through the silencer.

The engine shaft is coupled to the first-motion shaft of the change gearing by a coil clutch composed of a coiled spring, which surrounds the first-motion shaft and is carried by the boss of the fly wheel, and is controlled by a sliding cone on the shaft.

The sliding wheels of the change-speed gearing are mounted in pairs on sleeves which are moved to and fro along the shaft by longitudinal sliding rods; another rod is used to move the reversing pinion into gear. Each of these rods is toothed at its outer end, and a toothed segment on the spindle of the gear-changing lever may be moved endways to engage with any one of

them. The gear-changing lever works in a quadrant, having three guide slots communicating by gateways; the lever when in its vertical position may be moved sideways along its shaft from one slot to the other, and takes the segment with it, it may then be rocked into one end or the other of its slot to throw the change wheels into gear; the reversing slot extends on one side of the gate only. Devices are provided for locking two of the bars when the third is in operation, and the segment is coupled to the clutch so that this is automatically disengaged while the gearing is being changed. The second-motion shaft drives the compensating-gear shaft by bevel wheels, and this drives the road wheels by chains.

Expanding brakes, operated by toggles and a hand lever, are fitted inside the chain wheels; a band brake on the compensating-gear shaft and a third brake on the second-motion shaft are operated by pedals and provided with a water-cooling arrangement in which the water is turned on automatically as the brakes are applied.

The water tank for the brakes is in the frame, as also are the petrol tanks and the lubricating oil tank. The pressure of the exhaust gases is used to force the petrol to the carburetter, the water to the brakes, and the oil to the sight-feed lubricator on the dashboard. The frame is of channel section formed by flanging steel plates, and the axles are composed of steel tubes.

The Mors Cars

The Mors cars are built to the standard lines, but are fitted with a system of magneto-electric ignition, and contain many valuable improvements in detail. Here it will be sufficient to mention the gearing used in the latest racing car; the first and-second motion shafts of the variable-speed gearing are both geared by bevel wheels to the transverse shaft,

but the wheel on the end of the first-motion shaft is loose, and turns idly when the lower speeds are in action; when, however, the gear sleeve is moved to its extreme position, and the sliding wheels are out of gear, it clutches the loose bevel to the shaft, and the drive then becomes direct. Another feature is the use of pneumatic springs in addition to the ordinary steel springs for supporting the car.

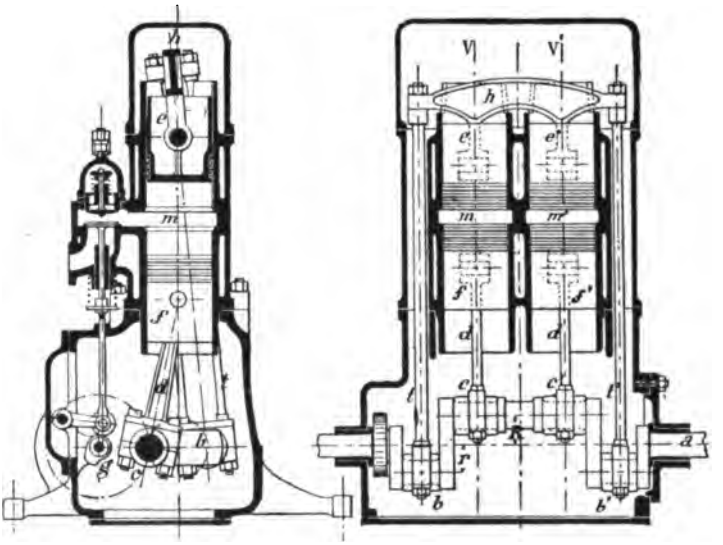
The Gobron-Brillié Cars

The distinguishing features of the Gobron-Brillié system are the balanced motor and the positive supply of combustible mixture. The cars are built in various forms, with the engine—*a*, in front under a bonnet, *b*, under the body of the car, and *c*, over the rear axle, and with various types of transmission gearing.

The balanced motor consists of two vertical cylinders, set side by side and each fitted with two pistons which work one above and the other below a central combustion chamber. Upon each explosion the upper piston is pushed upwards and the lower downwards. The lower pistons are coupled directly to their cranks and the upper to other cranks, placed diametrically opposite the former, by means of side rods which pass down on each side of the engine from a crosshead or beam, extending across the tops of the cylinders and formed with arms which descend into and are jointed to the pistons. Two sets only of valves and ignition plugs are required for what is in effect a four-cylinder engine. The combination works very smoothly and quietly.

Instead of the ordinary carburetter, a device for positively measuring out a charge of petrol for each stroke of the engine is employed. This consists of a cone fitted to rotate in a shell of corresponding shape, and formed with small cups or recesses round its conical surface. The petrol, fed into the casing, is carried by the cups over a

closely-fitting breast to a port in the casing which leads to the inlet pipe. Each cup carries one charge of petrol, and when it arrives opposite the port it also uncovers an air supply pipe, and forms a passage for the inrush of air to the cylinder upon the suction stroke, and the air of course carries the petrol with it. An auxiliary air supply is controlled by hand. The cone is rotated intermittently, to bring a cup opposite the port for each suction stroke of



a. Crank Shaft.
b, b^1. Cranks for Upper Pistons.
c, c^1. Cranks for Lower Pistons.
d, d^1. Lower Connecting Rods.
e, e^1. Upper Pistons.
f, f^1. Lower Pistons.
g. Cam Shaft.
h. Crosshead.
m, m^1. Combustion Chambers.
t, t^1. Side Rods for Upper Pistons.

THE GOBRON-BRILLIÉ ENGINE.

the engine, by a ratchet and pawl actuated by an eccentric. The speed of the engine is regulated by cutting off the supply when the speed becomes excessive; for this purpose a hit-and-miss arrangement is introduced into the gear for turning the cone, and this is controlled by an inertia governor, to break the connection between the eccentric

and the pawl. The governor presents several special features, but consists essentially of an oscillating balanced lever in combination with a spring.

The Bardon Cars

The horizontal balanced engine used on the Bardon cars works in the same way as the Gobron-Brillié, *i.e.*, two pistons work in the opposite ends of a long cylinder having a combustion chamber in the middle, but in this case the pistons are coupled to separate crank shafts, both of which are geared by bevel wheels to the first-motion shaft of the speed gear, which lies across the car. A loose sleeve on this shaft is coupled to it by a double cone clutch and carries the sliding wheels of the change gear; the second-motion shaft carries the compensating gear and drives the road wheels by means of chains.

In the smaller sizes of cars, single-cylinder engines, with two pistons, are used, and the exhaust-valve cams are mounted on the first-motion shaft which runs at half the speed of the crank shafts; in the large size, twelve horse-power, two cylinders are used, and a separate cam shaft is mounted upon the engine. The engine is controlled by a hand throttle on the inlet pipe and by a governor acting on the exhaust valves. To prevent back firing in starting, the variable-timing gear for the ignition is interlocked with the starting handle, so that this cannot be used without setting the ignition back.

The Chatel-Jeannin Car (Karminski)

The Chatel-Jeannin seven horse-power car presents several remarkable features. The engine and gearing is all mounted about the rear axle, which is made in two sections and enclosed in a cylindrical case having conical ends, which extend out to the wheels. The central part of

this case forms the crank chamber, and the horizontal engine cylinder projects from it towards the front of the car. The compensating gear is arranged between the crank pin and the crank shaft, this being formed in two halves each provided with a fly wheel and with a toothed wheel in gear with pinions on the ends of the crank pin, so that each half is free to rotate at a different speed to the other. The crank shaft is mounted to the rear of the axle, and each half drives the corresponding section of the axle by means of a pinion in gear with an internal wheel. One of the sections carries epicyclic speed and reversing gearing, which, however, is not in action for the high speed. Access to the case is obtained by means of a large door on the rear side.

The engine is fitted with electric ignition and a Longuemare carburetter; it is cooled by water, the radiator is in front of the car, and natural circulation is relied upon.

Notes on Other Continental Cars.

The GLADIATOR cars are built to the standard type and are fitted with Aster engines, the six-and-a-half horse-power with one cylinder, the twelve with two. Longuemare float-feed carburetters are used and the ignition is high-tension electric. The cooling water is circulated by a rotary pump, driven off the fly wheel; the radiator is hung from the front of the frame, and the water tank is in the rear. The petrol tank and accumulators are placed under the driver's seat. The twelve horse-power engine is provided with a governor controlling the supply of mixture to the cylinder.

The RENAULT cars have an ingeniously worked out variable speed gear, in which, at the top speed, the drive is direct from the engine to the longitudinal coupling shaft, and the toothed wheels are out of mesh and the second-motion shaft stationary.

The GEORGES-RICHARD cars have a live rear axle driven by bevel gearing and a universally-jointed coupling shaft from a change gear of the sliding-wheel type arranged to give a direct drive at the top speed. The change-speed lever is mounted on the steering column. The engines have the inlet valves in the centre of the cylinder ends and magneto ignition is employed.

The DECAUVILLE cars (ten horse-power) have a live rear axle and toothed wheel transmission gearing throughout; the speed gear is arranged for a direct transmission at the top speed and the gear box is fixed to the crank chamber. The engine is controlled by a governor acting on the exhaust valves. The ignition is electric, the current being supplied from accumulators which are kept charged by a small dynamo driven by the engine.

In the DARRACQ cars a live rear axle is driven, from a vertical single-cylinder engine in front, by longitudinal shafts geared together by a sliding-wheel change gear, the gear box being close up to the engine. The engine is governed by controlling the lift of the inlet valves.

The DÉCHAMPS cars are built on the standard lines and fitted with electric ignition and electric self-starter, by means of which the engine may be started from the seat by pressing a button. The band brakes on the wheels are in two half circles, drawn together by right-and-left hand screws.

The CLEMENT cars have a live rear axle like the Renault, the engine is on the same lines as the Centaure of Panhard & Levassor.

The DE DEITRICH firm seem, on some of their cars, to have gone back to a belt drive on to a first-motion shaft, connected by change gearing to a second-motion shaft which drives the rear wheels by chains.

THE GILLET-FORREST CARS.—The single-cylinder horizontal engine is arranged with its crank shaft transverse to the car, and geared by bevel wheels, enclosed in the crank chamber, to a longitudinal shaft which serves as the cam

shaft, and for transmitting the power of the engine through a friction clutch to the first-motion shaft in the gear box. The second-motion shaft transmits its motion through a coupling shaft and bevel gearing to the live rear axle. The change gear comprises a sleeve with two wheels adapted to slide on the first-motion shaft and to gear with wheels on the second-motion shaft, and a loose wheel on the first shaft always in mesh with the corresponding wheel on the second; this wheel is coupled to its shaft by sliding the nearest sliding wheel into it in the manner of a clutch. The engine is governed by varying the lift of the exhaust valves, the cam is of tapering formation, and movable along its shaft by means of the governor or by hand.

The ROCHET light car has a tubular frame which is made use of in conjunction with a radiator for the circulation and cooling of the jacket water. The circulating pump is mounted on the crank shaft of the engine, which is a two-cylinder vertical governed on the exhaust. The speed gear is of a special form in which but one pair of wheels are in mesh at a time, and the change from one speed to any other can be made directly; the clutch is arranged to disengage automatically when the gear is being changed. The engine and gear box are mounted on an underframe. The voiturette of the same makers has a four-and-a-half horse-power Aster engine in the rear of the car, and the gear is arranged for a direct drive on the high speed.

The ADER system is distinguished by the use of a two-cylinder engine in which the cylinders, set in the same vertical plane, are inclined to the horizontal, and form an angle of about ninety degrees with each other; the pistons work on to the same crank pin, and the crank shaft extends lengthways of the frame. The carburetter is of special construction, and the supply to the engine is controlled by a valve. The governor acts on a throttle valve, and is interconnected with the clutch and brake mechanism in

such a manner that the withdrawal of the clutch, or the application of the brake, automatically reduces the supply.

The RIEGEL converter is a motor on two wheels intended to replace the forecarriage of an ordinary vehicle in order to convert it into a motor car; the two wheels serve both for driving and steering.

The MERCEDES-LOHNER-PORSCHE and the CHAMPROBERT cars, and the JENATZY cars and omnibuses. All these employ an electric transmission system between the petrol engine and the road wheels. The engine works a dynamo machine, the current produced in which actuates electric motors connected to the wheels. This system allows a great range of speed to be obtained without the use of speed gearing. The Fischer omnibus, American, is built on the same lines.

AMERICAN CARS

The demand in America appears to be for a cheaper and lighter type of machine than that commonly used in this country. There are, however, a number of firms who produce machines of a higher class on the lines of the Panhard & Levassor cars; such are the Autocar Company, the Motor Car Company, the Fournier-Searchmont, the Peerless, the Gasmobile, and others. The Autocar tonneau has a horizontal two-cylinder balanced engine in front, the crank shaft lying lengthways of the car and coupled to the rear live axle by a sliding-wheel speed gear, a coupling shaft and bevel wheels. The Motor Car Company's sixteen horse-power car is fitted with a three-cylinder vertical engine, under a bonnet in front, which drives a rear live axle through epicyclic speed gear; the inlet valves are mechanically operated, the governor is applied to regulate the timing of the ignition, and the inlet pipe is fitted with a hand-controlled throttle valve.

The typical American car is, however, a smaller and handier vehicle, built more on the lines of the small steam car with which we have become familiar.

The Duryea Cars

Mr Duryea commenced building motor cars in the year 1891; in 1895 one of his vehicles won the Chicago *Times-Herald* race, and on the occasion of the motor-car run to Brighton, to celebrate the coming into force of the new Act in 1896, the performance of his car was much commented upon; he must therefore be looked upon as one of the veterans of the motor-car industry. The cars he is now

THE DURYEA THREE-WHEELED CAR, 1902.

building embody many interesting and ingenious features peculiar to themselves, the results of careful experimental work and long experience, and are remarkable for combined lightness and high power, as well as for simplicity of construction and ease of control.

The motor is mounted in the body of the car at a slight inclination to the horizontal. It is a ten horse-power three-cylinder engine with the cylinders placed side by side, and a three-throw crank shaft, having the cranks set at 120 degrees apart, placed forward of the cylinders and supported

by intermediate bearings between the cranks. The shaft carries, just outside the fly wheel, a Crypto gear which provides for a low speed and a reverse, and beyond this a chain pinion which drives, by the Duryea silent and self-lubricating chain, the chain wheel on the rear axle. The outer end of the shaft is supported in a bearing. The chain gear is enclosed in a case and gives a reduction of speed of about three to one. Under ordinary conditions, say for about ninety-five per cent. of the running, the Crypto gear is locked, and the transmission is direct from the crank shaft to the rear axle. The rear axle is made in one continuous length of nickel steel passing through both road wheels; one wheel is secured directly to it, the other to a sleeve fitting over it. The side members of the balance gear are of course fitted, one to the sleeve, and the other to the axle.

1. Conducting Wire to Anvils.
2. Exhaust Pipe.
3. Throttle Control Slide.
4. Mixture Supply Pipe.
5. Crypto Gear.

THE DURYEA ENGINE.

To return to the engine, the three cylinders and their water jackets are cast in one piece, and the valve boxes are formed on the upper sides of the casting. The exhaust valves are worked by cams on a half-speed shaft in the usual manner; they discharge into a common collecting pipe which leads to a silencer at the rear of the car. The inlet valves work automatically, but they are provided with a device for controlling the extent to which they open, and this constitutes the sole provision for regulating the speed of the engine. For this purpose a controlling slide, slotted to allow the valve stems to pass through it, is mounted

across the ends of the cylinders and is movable to and fro endways, and, being formed with inclined guide slots which work over fixed pins, also crossways, *i.e.*, to and from the valves. The stems have collars outside the slide; when the slide is in the position most remote from the valves it draws them hard against their seats; as the slide is moved endways and inwards, the valves are allowed to open to a proportionate extent, and thus any desired throttling of the charge may be obtained. In the extreme inward position of the slide, springs carried thereby come over the heads of the valve stems and press them inwards; this forms a ready means for relieving compression in starting the engine.

The petrol tank, placed under the footboard, supplies by gravity a float-feed device, the nozzle of which is placed concentrically in the air-supply pipe. The float-feed chamber is provided with a vent pipe which extends above the level of the petrol in the tank, and in the branch leading to the nozzle is a needle valve controlled by hand to regulate the supply of petrol. The spray and the air are mixed together as they pass along the pipe to the inlet valves.

The ignition is effected by a low-tension electric current produced by a magneto machine, driven by a flexible shaft and a little friction pulley from a conical edge on the fly wheel. The friction pulley is mounted to slide on its shaft under the control of a centrifugal governor; when the speed becomes too high, the pulley is automatically drawn back. One terminal of the magneto is connected by a single wire to the three sparking anvils in the valve boxes. The sparking hammers are carried through the exhaust valve stems, which are made hollow for this purpose normally they are pressed into contact with the anvils and thus afford a direct path for the current; at the moment for ignition they are drawn back sharply and the rupture of the circuit is accompanied by a spark. The movement of the hammers is one of rotation; it is produced by springs

and cams on the half-speed shaft. The sparking points and the valves may be inspected by removing the caps of peep-holes in the valve boxes. A battery is provided for starting the engine, but the magneto comes into action very quickly.

The removal of the bottom and panels of the seats affords easy access to the engine, gearing, magnets, etc. Each cylinder is lubricated by a separate oil cup, and as Mr Duryea is an advocate for working the cylinders at as high a temperature as possible, a special lubricating oil is recommended.

The cooling water is supplied from a tank behind the seat by natural circulation.

The steering heads or pivots upon which the ends of the front axle turn are inclined to the vertical, their centre lines meeting the ground at approximately the centres of the wheel treads. In steering the wheels consequently turn about points in their own planes, so that the required angular position is at once obtained and the steering becomes very sensitive; at the same time an obstruction fairly met has no effect in changing the direction of the wheel. The arms on the steering heads are coupled by tension rods to the steering handle, which is mounted at the front of the seat between the two riders and is moved to and fro transversely to the car.

The control of the entire machine is effected by the steering handle; by twisting the hand grip the slide which controls the inlet valves is moved endways; by moving it up or down the gear is controlled; in its middle position, where it is locked by a spring catch, the engine runs free, *i.e.*, disconnected from the car; when drawn to its topmost position the high-speed clutch is engaged, and when in its lowest position the low speed is thrown into action. The reverse is actuated by a pedal, as is also a band brake in the chain wheel on the rear axle. Extra brakes acting on tyres of the rear wheels are also provided, but the throttling of the engine is found to be perfectly effective in retarding the speed of the car when desired.

The distribution of the parts throws the weight mainly on the driving wheels, and the steering wheels are very lightly loaded. The wheels are of large diameter; this combined with the light load[1] they have to support, gives the tyres a fair chance of standing well. The wheel base is long and the springs are of good length. The type of engine, the absence of gearing for ordinary work and the silent chain combine to make this car a very quiet, easy-running machine. Its ample power allows all but excessively steep hills to be ascended with the direct drive. In addition to the phaeton illustrated, tonneau and surrey bodies are also fitted. The Duryea Company also make the phaeton as a four-wheel vehicle.

Notes on Other American Cars

The Oldsmobile is a light car to seat two persons, with the body mounted on long springs, which extend from the front to the rear axle. A single-cylinder horizontal engine, with a heavy fly wheel, is mounted in the body of the car with the combustion chamber to the rear; both inlet and exhaust valves are mechanically operated. The carburetter is of special construction; the pulsations of the air in the crank chamber, caused by the movement of the piston, by acting upon a flexible diaphragm, forces up the petrol from the main reservoir to a small tank above the level of the carburetter; from there it flows down, and is admitted by valve into a cone of wire gauze suspended in a chamber through which the incoming air is sucked; the air plays round the cone, takes up the petrol, and carries it on to the cylinder. The current for the electric ignition is provided

[1] The car weighs from 800 to 1000 pounds, of this the engine accounts for nearly 200 pounds; it is supported on thirty inch and thirty-six inch wooden wheels with Goodyear tyres. The wheel base is five feet six inches and the gauge four feet eight inches. The engine has cylinders four and a half inches diameter by four and a half inches stroke; the normal speed is 700 to 800 revolutions per minute, but it may be run up to 1200 or 1500, and down to as low as seventy-five revolutions per minute.

by means of dry batteries, and the timing lever is placed at the side of the seat. The radiator is placed under the footboard, and the water and petrol tanks in the rear. The engine is started from the seat by means of a crank and a flexible shaft, and the operation is facilitated by relieving the compression by means of a special cam which keeps open the exhaust valve. The engine shaft carries trains of epicyclic gearing to give a low speed and a reverse, and motion is transmitted to the rear axle by means of a chain.

The PIERCE, the HAYNES-APPERSON, the BUFFALO, the RAMBLER and many other American light cars are built on the same general lines as the Oldsmobile, with single-cylinder engines in the body of the car, epicyclic speed-reducing and reversing gear, and chain drive to rear axle. In some cases the inlet valves are mechanically operated.

The ELMORE car is driven by a two-cylinder vertical engine working on the two-stroke cycle, placed under the seat. The transmission is effected by means of a chain to the epicyclic speed and reversing gear, and thence by another chain to the compensating gear on the rear axle. For the high speed the epicyclic gear is inoperative. The engine is governed on the admission, and the ignition is electric, the current being supplied by a dynamo worked by the engine; but for starting, accumulators, charged from the dynamo, are provided. The cylinder cooling water is pumped through a special form of cooling tank in front of the car.

The FRIEDMAN car has a variable-speed friction gear, connecting the engine shaft to a countershaft, from which the rear axle is driven by chain. The engine is a two-cylinder balanced engine, and has mechanically-operated inlet valves.

CHAPTER XIV

MOTOR CYCLES

FOR many years efforts have been made to apply motors to velocipedes. Some of these have been alluded to in preceding chapters, and it has been shown that the very first attempt made by Daimler in applying his motor to road locomotion was made in connection with a bicycle, while that of Benz was made on a machine which may fairly be termed a tricycle; but in spite of their having been the subject of the earliest experiments of Daimler and Benz, and of Butler in England, it was only after the petrol car had attained to the position of a workable machine that any degree of success was attained with petrol cycles, and it was the tricycle which first arrived at what may be termed some degree of maturity. The De Dion-Bouton machine made its first appearance in 1895, and in a few years was advanced to the condition of giving very satisfactory results on the road.

The petrol bicycle, although the subject of Daimler's first experiments, and although it was manufactured and sold in some numbers by Hildebrand & Wolfmüller in 1895, unfortunately not with successful results in practice, only attained the condition of a practical success on the road after the tricycle had made considerable headway. It is to all intents and purposes the creation of the last few years, but already it has taken possession of the field and bids fair to oust the tricycle and quadricycle entirely. It is not difficult to see why this is so. The motor bicycle possesses the same advantages over

the motor tricycle and the motor quadricycle as are found in the case of the ordinary pedal-driven machines; its two wheels running in the same track render it possible almost always for the rider to select a smooth path even on a bad road; it can be handled, taken through doorways, and carried by rail with greater facility. On the other hand, the three and four-wheeled machines will stand alone when stationary, and are less liable to side slip. But perhaps the chief consideration in favour of the bicycle is that of cost. A motor bicycle by a good maker may be bought for say £40 to £50, and the cost of upkeep is fairly low. A tricycle will cost perhaps £25 or £30 more, it will require a special house to be built for it, and the upkeep will be more expensive. The motor car will always of necessity be a comparatively costly machine, and as far as possession goes, the initial cost and the cost of maintenance will restrict its enjoyment to the comparatively well-to-do, but the extra cost of the tricycle as compared with the bicycle goes some way towards making up the cost of a car, and to many who can afford to go beyond the price of the bicycle it will undoubtedly appear advisable to make an effort to go still further and procure a voiturette or light car, which is a far more satisfactory and complete vehicle.

This leads to a consideration of the distinction to be drawn between the car and the cycle; as a matter of fact, the two forms merge into one another, and it is a difficult matter to frame definitions which shall accurately delimit each class; at the same time, the general notion that the car has a carriage body and enclosed motor and driving mechanism, whereas the cycle is provided with pedals, and has saddles or seats mounted on an exposed tubular frame, and the motor and driving mechanism not enclosed, is quite near enough for all ordinary purposes.

Many experiments have been and are being made in connection with the application of steam and electric motors, but the motor cycles on the market to-day are

without exception propelled by petrol engines. The main principles of the construction and action of these engines have been dealt with in the chapter on the Petrol Motor, to which the reader is referred. It will be sufficient here to note the special points in so far as they relate to cycles, and to consider the position of the engine in the frame and the systems of gearing adopted for transmitting power to the driving road wheel.

With few exceptions single-cylinder air-cooled engines are employed, and the standard horse-power is from one and a half to two; but the tendency is towards higher powers, and the motor bicycle from being a motor-assisted pedal-driven machine has already become a motor-driven machine in which the pedals are retained simply to assist in starting the motor, and for assistance in ascending unusually steep hills, and now even this assistance is being dispensed with, and motors of sufficient power to ascend at considerable speeds the steepest hills met with on English roads are being fitted in some cases. But it is very doubtful whether this increase in engine power is really desirable for ordinary purposes, that is to say for machines that are intended for use on common roads and not for racing. One should certainly be guided by circumstances. For a very hilly district or a heavy rider higher power would be an advantage, but in general the engine which will give off one and a half horse power at the engine shaft should meet ordinary requirements. This power is sufficient to cover average undulating roads at a really good speed, and it will take a trailer behind at from ten to twelve miles per hour. Increased power means a heavier and more cumbersome machine, and one of the chief advantages of the motor bicycle, its facility for handling, is lost or reduced. Again a larger engine, to work with equal efficiency, should be cooled by water, and this can be effected only at the cost of additional complication and weight. The large engine no doubt enables the machine to run up hills at higher speeds, but it works at a disadvantage at the lower power

required for flat roads. On the whole, the better course appears to be to retain the smaller size of engine and to fit the machine with a two-speed gear, which would enable the power exerted on the wheel to be increased, at the expense of speed, when ascending hills, while on the level the engine could still be allowed to work at something approaching its full power. Assisting such a machine with the pedals from time to time would be a pleasure for most riders, and in the event of a breakdown it will not be so heavy as to render pedalling it home out of the question.

To return to the construction of the engine, the fly wheel is usually enclosed in the crank chamber, with the crank shaft in two parts, and a separate crank pin. This certainly forms a very compact arrangement, but the use of an external fly wheel has the advantage of permitting the crank shaft to be made in one piece, and of allowing a wheel of larger diameter to be employed, which for the same weight will be a far more efficient regulator, or rather accumulator, of the power of the engine. This plan is being adopted by several makers. Surface carburetters are in extensive use, but the tendency seems to be to adopt some form of spray apparatus, with or without a float feed. The ignition is invariably electric, and most commonly on the high-tension system, with accumulator and coil, although the magneto system is in use and appears to be gaining in favour in spite of being somewhat heavier. The petrol tank is usually made of sufficient capacity to take a supply for a run of 100 miles. The accumulator will last eight or nine times that distance.

The use of the cock at the top of the cylinder for relieving the compression in starting the engine is gradually giving place to the exhaust-valve lifter, a device by which the exhaust valve is kept open at will, so that it serves the same purpose in a more efficient manner and is also available as a means for controlling the engine, which it is found to do in a very effective manner. It should be explained that when this valve is kept open on the suction stroke, air

or waste gas rushes back through it into the cylinder, and this prevents or reduces the opening of the inlet valve so that it becomes possible to dispense with the valve in the inlet pipe entirely. The opening at the top of the cylinder is retained for the purpose of injecting kerosene or petrol when it is required to clean the cylinder and piston from an accumulation of lubricant.

In the motor car the practice of placing the engine under a bonnet in the front of the vehicle has become so general that it may be said that a normal type has been arrived at. In the motor bicycle this is not so, and a great diversity of practice prevails in reference to the position of the engine. The Singer machine has the engine enclosed in the driving wheel; in the Enfield it is secured to the frame above the front wheel and in front of the handlebar; in the Minerva group of machines the engine is secured to the down tube, the tube extending from the steering head to the crank bracket, while in the Werner, Precision and others a vertical engine is fitted near the crank bracket. The arrangement of the engine, whether horizontal, vertical, or inclined, is not a matter of first-rate importance as far as the working of the engine itself is concerned. It has been advanced in favour of the vertical position that horizontal and inclined cylinders tend to wear oval in consequence of the weight of the piston, but when it is considered what a small proportion this weight bears to the side pressure exerted by the piston on the cylinder in consequence of the side thrust of the connecting rod, it will be seen that it is a factor of little importance, and as far as this point is concerned the angle at which the cylinder is placed may with safety be left for determination by other considerations.

In determining the position of the engine in or on the frame a number of points have to be kept in view: the stability of the entire machine, the straining actions of the motor and transmission gearing, accessibility of the valves and other mechanism, suitability for the system of trans-

mission to be employed, lubrication of the cylinder and the desirability of freely exposing it to the air in order to obtain the maximum cooling effect. Further, the engine should be placed so as not to interfere with the comfort of the rider, and at the same time be removed as far as possible from the mud and dust of the road. Many of these desiderata are mutually antagonistic, and what must be sought after is the best all-round result.

The lubrication of a motor working at the high temperature and speed of the petrol engine is clearly a matter of the highest importance which it is somewhat difficult to bring home to the rider accustomed to the ordinary bicycle. The oil employed is a mineral oil of high flash point, capable of standing high temperatures without decomposition; at the ordinary temperature of the atmosphere it is very thick or viscous, but under the heat of the engine it becomes thin. The system usually adopted is that of splash lubrication; a charge of oil is introduced, preferably by means of a pump, into the crank chamber at regular intervals, say of fifteen to twenty-five miles, according to the condition of the engine, etc.; the crank in its rotation splashes this about over the wearing parts contained in the crank chamber and into the cylinder. The crank chamber should not be overcharged as there is then a danger of the oil working through by the piston into the combustion chamber, and causing the deposit of carbon on the sparking points, the sticking of the valves, and smell and smoke in the exhaust. In some cases the supply of oil is continuous and automatic; this is the ideal arrangement, but of course there is the chance of the feeding device failing to work and the possibility of disastrous results to the engine.

The mechanism for transmitting the power of the engine to the road wheel is a most important element in the construction of a motor bicycle. With a few exceptions, the means adopted are either belts or chains. Some makers use flat belts working on flat pulleys, others round

or V-section belts working on grooved pulleys. The round belts are usually formed of twisted raw hide and may be tightened up by further twisting. Belt transmission has many advantages, it is silent and elastic, it absorbs some of the inequalities in the driving effort and does not transmit to the road wheel the violent impulses which occur on the working of the engine. On the other hand, belts even under the most favourable conditions stretch when at work, and cease to grip the pulleys, and thus fail to transmit the motion until they are shortened. In the motor cycle the conditions are about as unfavourable as it is possible to conceive for the satisfactory working of a belt; the very feature which appears to render them specially suitable, that of preventing the transmission of jerks or violent impulses, is detrimental to them. With an engine shaft rotating at a most irregular angular velocity, as it must do with the small fly wheels employed, and a driven part rotating at a fairly uniform velocity in consequence of the momentum of the entire machine, it is clear that if it does not snap, as it frequently does, the belt must periodically yield by stretching or by slipping on the pulleys; both actions occur and both are bad; the periodic stretching increases the tendency of the band to elongate, and the slipping grinds away the pulleys and absorbs power. But there is another and still more important consideration, in particular if an all-weather machine is required, the damp and mud render it practically impossible for a belt to do good work in wet weather. The chain has proved itself capable of doing good work in connection with the ordinary bicycle in spite of wet and mud, but it must be borne in mind that a chain gear forms a positive connection between the driving and driven parts, and that where the belt would momentarily yield or slip the chain would snap under sudden jerks. Failing, then, the possibility of fitting an engine, the shaft of which shall rotate at a uniform speed throughout its cycle of two revolutions, which is out of the question with a single-

cylinder engine and a fly wheel of reasonable weight, it appears essential that the driving-chain wheel should be connected to the engine shaft by some yielding connection, such as a friction coupling, which would slip under sudden jerks, or a spring coupling. The latter is the preferable arrangement as the excess of power would be expended upon the spring, which would give it out later on and thus tend to equalise the driving effort, whereas in the friction coupling it would be lost in producing friction and heat.

The tyres fitted to motor bicycles are usually two-inch pneumatic tyres specially made for the purpose. The leading makers now produce tyres which give remarkably good results. The seat pillar and the steering head should be fitted with springs to prevent as far as possible the transmission of the vibration of the motor to the person of the rider.

Side slip with rear-wheel driving and the engine fairly low down in the frame is not a serious difficulty. Greater care, however, is required in steering and in applying the brake to the front wheel than with the ordinary bicycle, in consequence of the greater weight and speed of the machine and the resulting increased momentum.

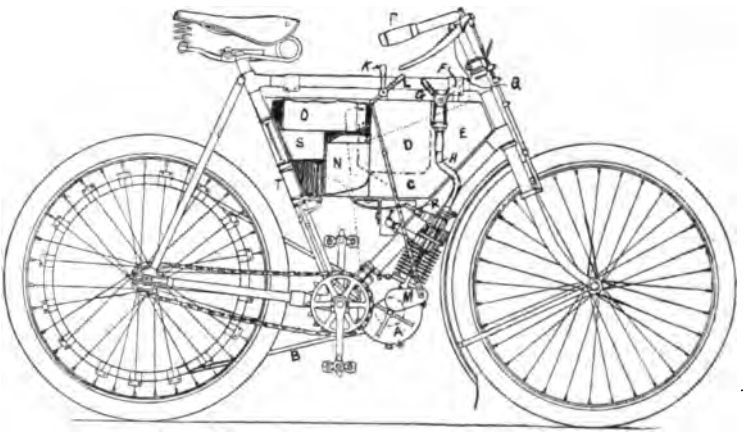
Two independent brakes are required by the provisions of the Light Locomotives Act, which applies to motor bicycles as well as to motor cars.

The Minerva Motor

The Minerva motor, manufactured at Antwerp, is very extensively used[1] in connection with motor bicycles, and has undoubtedly given good results in practice. It is a single-cylinder air-cooled engine of one and a half horse-power, with the fly wheels enclosed in the crank chamber, and is adapted to be clamped in front of the inclined tube which connects the steering head to the pedal crank

[1] It appears that upwards of 3000 have been sold since the beginning of 1901.

bracket, the down tube of the ordinary diamond pattern bicycle frame. The petrol tank, carburetter, coil, accumulator, and receptacle for lubricating oil, are all contained in a case which fits inside the frame and is secured to the top bar. The carburetter is of the surface type; it is formed by a compartment underneath the petrol tank, and petrol is allowed to flow into it by a valve, the stem of which extends up through the tank and protrudes on one side of the top bar of the frame, where it is provided with a knob



A. Engine.
B. Driving Band.
C. Carburetter.
D. Petrol Tank.
E. Vapour Chamber.
F. Air Valve.
G. Gas Valve.
H. Inlet Pipe.
I. Silencer.
K. Handle for Compression Valve.
L. Handle for Contact Breaker.
M. Contact Breaker
N. Accumulator.
O. Coil.
P. Switch (in left hand grip).
Q. Interrupter Plug.
R. Sparking Plug.
S. Oil Reservoir.
T. Oil Pump.

THE MINERVA MOTOR BICYCLE.

and nut for adjusting the flow. The amount of petrol in the carburetter is indicated by a float, the stem of which likewise passes up through the tank and protrudes at the top. Air is supplied by a tube or chimney which extends down through the tank into the carburetter, where it is perforated, and is fitted at its upper protruding end with a

cap by which the air supply may be regulated. The vapour as it is formed accumulates in a compartment in front of the tank, at the top of which is a double valve through which it passes to the cylinder. This valve has one handle for regulating or throttling the supply of gas or mixture, and another by which the supply of additional air for admixture with the highly carburised vapour formed in the carburetter is adjusted. These levers are sometimes called the gas lever and the air lever respectively; they stand one on each side of the top bar, and just behind the handlebar. To the rear of them are two other handles, one for opening a small valve in the top of the cylinder, in order to reduce compression in starting, etc., and the other to move the contact breaker case round the cam shaft, for the purpose of advancing or retarding the ignition. The primary circuit for the electric ignition is opened or closed to stop or start the machine by a switch in the handlebar operated by twisting one of the hand grips. The wire from this switch to the accumulator passes through an insulated block, fixed on the top bar just behind the steering head, in which its continuity is broken. The block is, however, fitted with a plug, the interrupter plug, which when inserted couples the two ends of the wire, whereupon by turning on the switch the current from the accumulator is caused to flow through the primary circuit. Of course this plug is kept in place while the machine is in use, and is removed at the conclusion of a run, so that the machine cannot be started by anyone not in possession of it; its removal also prevents the possibility of the accumulator running down. The engine is lubricated by introducing a charge of oil from time to time into the crank chamber by means of a pump on the seat pillar, which may be worked by the rider from the saddle. The transmission of power is effected by a round band passing over a grooved pulley on the engine shaft and over a grooved ring which is fixed on the spokes of the rear wheel. At the normal speed of 1500 revolutions per

minute the machine runs at the rate of twenty miles an hour. The motor set comprises all the parts necessary for the production of the motive power, its regulation and transmission to the driving wheel, and weighs forty-five pounds.

The Excelsior, Phœnix, Quadrant, Whirlwind and Bradbury Motor Bicycles

All these belong to the Minerva group, and have the engine secured to the down tube in front of the crank bracket.

The Excelsior is provided with an exhaust-valve lifter instead of the compression-valve lever, and with a spring head to absorb vibration. In addition to the standard one and a half horse-power machine, the makers also build one with a two and three quarter horse-power motor.

The Phœnix is also provided with an exhaust-valve lifter, operated by a Bowden wire from a thumb-piece on the handlebar, and the electric switch is combined with the valve lifter, so that pressure on the thumb-piece first breaks the circuit, and then, if continued, opens the exhaust valve. The lubricating pump is of special construction, and an extra petrol tank is mounted between the seat pillar and the back wheel, which brings up the supply to sufficient for a run of 200 miles. Another feature in this machine is that the gas and air levers are made of considerable length to facilitate fine adjustment of the valves. The machine is built with a diamond type frame for a single rider, and also as a tandem with a drop rear frame to allow of the second seat being occupied by a lady.

The Quadrant bicycle has for its distinguishing feature a one-lever control. The current for ignition is turned on or off, the exhaust valve lifted, the supply of gas regulated and the time of ignition adjusted, and in fact the entire manipulation of the machine when travelling is effected by

a single handle. For this purpose, the handle of the gas valve is provided with a wing to serve as a switch for the electric circuit, and with a lever which is connected by a depending link to the contact breaker and to the valve lifter. In its extreme position one way the switch is off; that is to say, the circuit is broken, the supply valve is closed and the exhaust valve open. A slight movement of the handle switches on the current, closes the exhaust valve and partly opens the gas valve; the next movement opens the gas valve to its full extent. After this, movement of the handle advances the ignition and then begins to close the gas valve—this is the position for running under favourable conditions. The engine is stopped immediately by moving the handle back to its original position. Another handle is provided, as in the Minerva, for regulating the quality of the mixture, but this seldom requires adjustment.

The Werner, Precision, etc., Motor Bicycles

The firm of Werner Frères was among the first, if not the first, to embark upon the manufacture of motor bicycles, and the Werner machines have done remarkably well in various public contests; they distinguished themselves in the Paris-Vienna race of 1902, for instance. The machines of past years were front drivers, with the engine mounted in front of the handlebar and transmitting its motion to the front wheel by a belt. The 1902 Werner machine, however, has the engine, vertical, low down between the two wheels, and built into the frame to form the junction between the down tube and the saddle pillar, and the rear wheel is driven by a flat belt. The carburetter is of the spray type. The rear-wheel hub is fitted with a band brake applied by hand, and the front wheel with a rim brake.

The Precision has the engine built into the frame in a somewhat higher position than the Werner. A carburetter of the spray type is used, and the fly wheels, which are

enclosed in the crank chamber, are each formed integrally with one of the shaft sections, and the crank pin is formed on one of them. The transmission to the rear wheel is by means of a flat belt. The electric switch and the exhaust-valve lifter are worked by the same handle and a Bowden wire. The Precision Motor Company make another type of machine, in which the motor is inclined and carried between the down tube and another parallel tube in front of it. The machines are fitted with engines of one-and-three-quarters or two-and-one-eighth horse-power.

The Rex is fitted with a two horse-power engine in much the same position as the Werner and the Precision.

In the Regina the same position is adopted, but with a special form of frame. This machine is fitted with a two and a half horse-power De Dion-Bouton water-cooled motor with a cooling radiator on the steering head, with a two and a quarter horse-power De Dion-Bouton air-cooled motor, or with a two horse-power Regina motor.

In the Clyde, the seat pillar and down tube are in one piece, bent under the crank chamber of a two-horse-power vertical engine, which is fitted with magneto ignition. The same construction of frame is met with in a German machine, the Opel.

The Royal Sovereign and the Calvert machines have the engines closer up to the front wheel and carried in specially-designed frames. Another design of the Calvert machine, however, has the engine placed as in the Ormonde.

The Hewetson (Laurin-Klement) also has the vertical engine in the front part of the frame but close up to the top bar. Magneto ignition is employed in this engine, and the magneto machine is placed below the engine.

The F. N. Motor Bicycle

This machine, made by the celebrated firm, the Fabrique Nationale d'Armes de Guerre of Liege, has a

one and a quarter horse-power engine placed vertically above the crank bracket, and the transmission is by means of a flat belt which runs on a wooden rim secured to the spokes of the rear wheel. One of the special features of the engine is its outside fly wheel of large diameter. The cylinder, cylinder head and the top half of the crank chamber are made in one casting, and the sparking plug is screwed into the centre of the cylinder head. The carburetter is of the float-feed spray type, and the air intake is placed in close proximity to the side of the cylinder in order to warm the entering air. The contact breaker is of quite a special form; the cam works inside a ring pivoted in the case, which can be turned on the cam shaft as usual to vary the period of ignition. The insulated wire from the accumulator is secured to a terminal, screwed into the case, opposite the platinum tip of which is a platinum contact on the ring; the ring is oscillated to make and break the contact by the action of the cam and a spiral spring which bears on a projection on the ring. The machine is controlled by a switch in the left hand grip of the handlebar, which serves to open or close the primary electrical circuit, a lever for advancing or retarding the time of ignition, and a handle for working the compression tap

The Ormonde Motor Bicycle

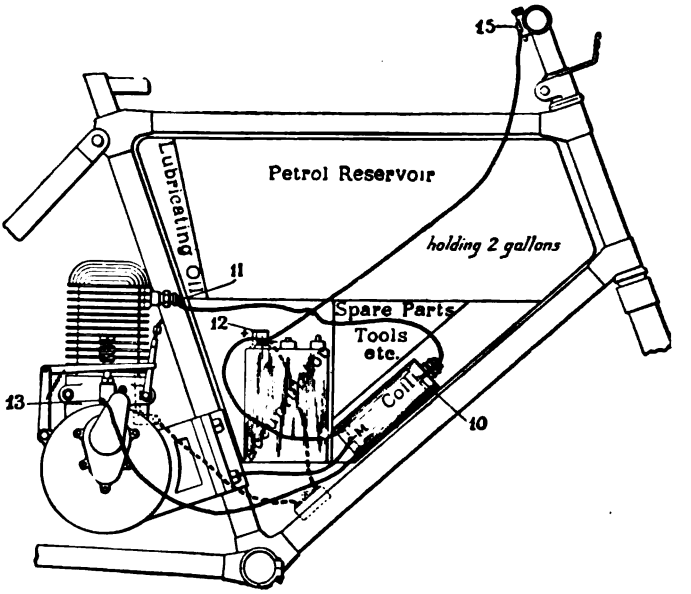
In this machine a vertical engine is clamped behind the seat pillar and drives the rear wheel by means of a round or a V-section band working on grooved pulleys. The engine, the Kelecom, is of foreign manufacture and presents several interesting features; it gives off one and three-quarters horse-power at the crank shaft when running at 1500 revolutions per minute. The cylinder and head are in one casting, which is screwed into a neck formed on the crank chamber. This is divided in a vertical plane into two halves, which are bolted together and enclose the

fly wheels which also serve as crank discs. The engine is fitted with an exhaust-valve lifter operated by a Bowden wire transmission from a twist handle on the handlebar. The valve lifter is combined with a switch in the primary electric circuit; for this purpose the horizontal valve-lifter lever is formed with a downwardly-projecting arm adapted to work over an insulated contact fixed to the crank chamber, the arrangement being such that the first twist of the handle moves the arm away from the contact and breaks the circuit, and a second twist lifts the exhaust valve. The one handle thus gives full control of the

THE ORMONDE MOTOR BICYCLE.

motor. There is besides a small handle on the top bar for advancing or retarding the ignition, and a second handle for controlling a valve placed in the inlet pipe between the carburetter and the inlet valve. The carburetter is a very neat form of the float-feed spray type, and has been found to give uniform results in all weathers and over good or bad roads; the air supply is heated by contact with the exhaust pipe, and the quality of the mixture is controlled by a cap which regulates a secondary air supply, but this once set, requires no further adjustment. The front compartment of the frame is fitted with a casing bevelled at the front and rear ends to reduce the air resistance and to avoid screening the engine from

the rush of air. The upper part of the casing forms a tank capable of holding two gallons of petrol, and a small reservoir holding about one and a half pints of lubricating oil. The accumulator, coil, tools and spare parts are carried in the lower part of the casing. The lubrication is effected automatically and continuously by means of



The high-tension terminal 10 of the coil is connected to the sparking plug 11 ; the terminal M to the frame of the machine for the return circuit ; the terminal T to the contact breaker 13, and the terminal + to the positive terminal 12 of the accumulator. The negative terminal 14 of the accumulator is coupled as shown in dotted lines to a contact on the crank chamber, over which works a switch formed on the exhaust lifter. The interrupter shown at 15 has now been abandoned and the switch arrangement actually employed is somewhat different to that shown.

THE ORMONDE MOTOR BICYCLE. DIAGRAM OF ELECTRICAL CONNECTIONS, ETC.

a lubricator fixed on the crank chamber, and fitted with a spring valve which is opened by the vacuum produced upon each upward stroke of the piston, and allows the passage of a small quantity of oil at each opening. The

lubricator is in communication with the oil reservoir by means of a pipe. The weight of the complete machine is about seventy-five pounds.

The Humber Motor Bicycle

In this machine the inclined tube proceeding from the fork to the crank bracket is replaced by a member composed of four smaller tubes between which the engine, of two horse-power, is mounted. Power is transmitted to the rear wheel by chain gearing; the chain wheel on the engine shaft is driven by a friction coupling held up by an adjustable spring; this construction prevents the transmission of sudden jerks or shocks from the engine to the chains; from this wheel a chain proceeds to a chain wheel on a hollow shaft fitted over the pedal crank axle. Other sets of chain gearing connect the hollow shaft and the crank axle to wheels mounted on the hub of the rear wheel and fitted with free-wheel clutches. The crank axle may be coupled to the hollow shaft, for the purpose of starting the engine, by means of a pawl and ratchet wheel; the pawl may be turned back by the foot of the rider when it is required to propel the machine by the pedals. The carburetter usually fitted is of the surface type; it is provided with a float feed, and the air supply is warmed by contact with the cylinder; a mixture valve permits the current of air to be divided into two parts in varying proportions; one part is deflected over the surface of the petrol and the other

THE HUMBER MOTOR BICYCLE.

part is sent on direct. No throttle valve, compression tap or exhaust-valve lifter is provided. In lieu of the latter a half-compression cam is mounted on the cam shaft, which, when brought into action, keeps the exhaust valve open during the earlier part of the compressson stroke, thus relieving the compression while it allows of the entry of a partial charge sufficient to run the engine; this cam is operated by the ignition lever when this has been moved towards its extreme position. The interrupter switch is combined with the front-brake lever; when this lever is lifted the circuit is broken and the engine stops, further movement applies the brake. Lubricating oil is supplied to the crank chamber by means of a pump, but the crank shaft and cam-shaft bearings are fitted with drip lubricators.

The Clement-Garrard Bicycle Motor

The engine, which is of very light construction, weighing only twenty-one pounds, is placed in a position similar to that of the Humber machine, fixed on and parallel to the down tube; it has the valves mounted on the cylinder head and an outside fly wheel. Two systems of transmission gear are fitted, *i.e.*, either a belt passing over a jockey pulley, or chain gearing. In the latter an intermediate spindle is mounted just in front of the pedal crank axle; this carries a two-speed gear and is coupled to the engine shaft and to the rear wheel by chains.

The Enfield Motor Bicycle

The engine, of one and three-quarters horse-power, is mounted parallel to the steering head in front of the machine and above the steering wheel. This position is well above the mud and dust of the road and fully exposed to the air; it would seem, however, that it might have some effect upon the stability of the machine, but this is stated

by persons who have used the machine not to be the case. The carburetter is of the spray type but no float is used, the supply of petrol being regulated by a hand-adjusted needle valve. The stem of the inlet valve is arranged to project outwards through the top of the dome, so that the free working of the valve may be tested with the fingers. The engine is controlled by means of an exhaust-valve lifter, the operating handle of which is on one side of the handlebar. The electric switch is on the other side. The power of the engine is transmitted to the rear wheel by means of a crossed belt of V-section.

The Derby and the Mountaineer Motor Bicycles

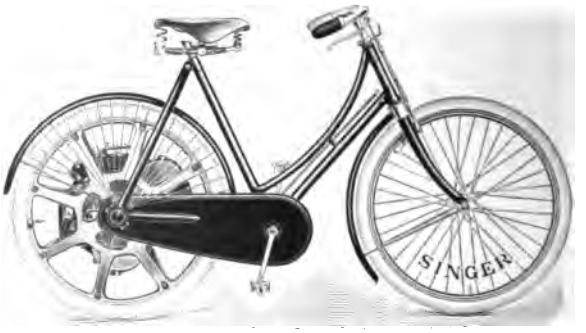
In the Derby the engine is mounted inside the frame and parallel to the down tube, and power is transmitted from it by a chain to an intermediate shaft, which in one arrangement drives the rear wheel by means of a friction wheel pressed into contact with the tyre, and in another by means of a band and pulleys. The intermediate shaft is mounted on a pivoted arm, which can be moved by a hand lever, in the one case to press the friction wheel against the tyre, and in the other to tighten the band.

The Mountaineer has the engine in the same position, but it drives the rear wheel direct by means of a band.

The Singer Cycles

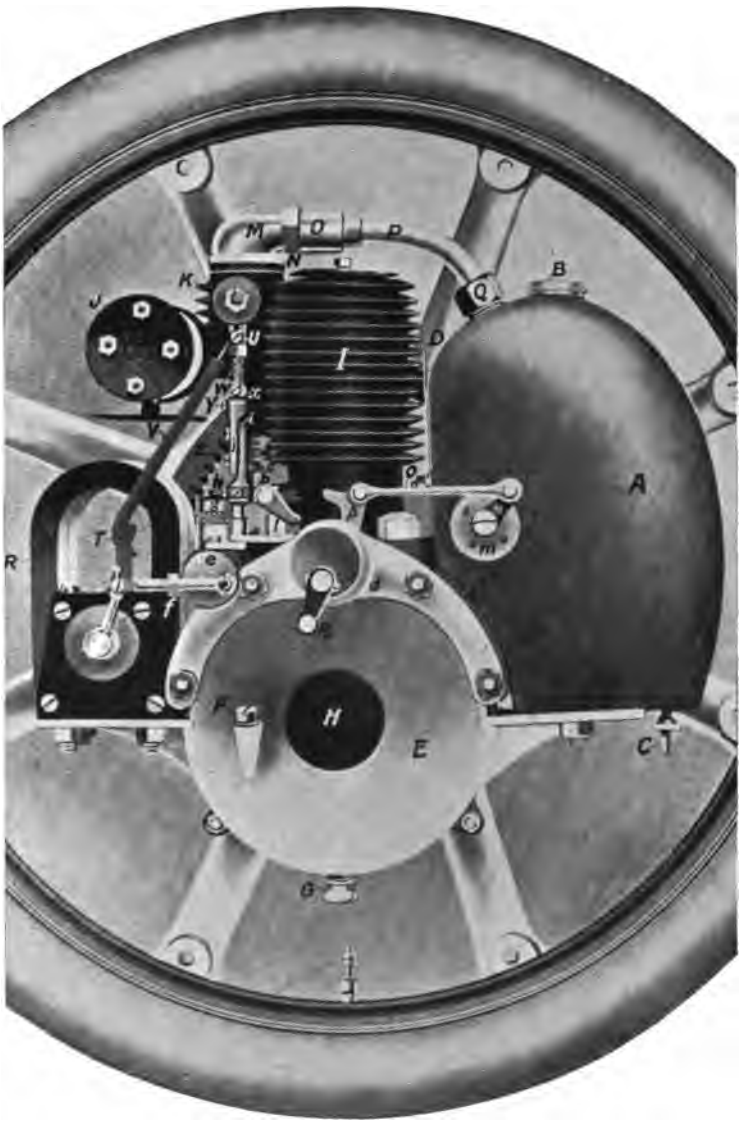
The special feature of the Singer system lies in the position of the engine, which is enclosed in one of the road wheels. This wheel, instead of the ordinary wire spokes, has, clamped to the rim, two aluminium sides, the hubs of which are adapted to run on the bosses or trunnions that serve to connect the engine to the frame. The trunnions are formed on wings, which are bolted to the engine crank chamber, and project through the hubs into eyes in the

frame members, wherein they are securely fixed. The engine, which stands vertically, drives the wheel by gearing, and has on one side of it the carburetter, which is a special form of the surface type provided with a float feed, and on the other side a Simms-Bosch magneto machine for generating current for the ignition, which is on low-tension system, with a make and break inside the combustion chamber. The magneto machine is worked by a crank disc, on the cam shaft which works the exhaust valve, and the sparking device or current interrupter is operated by a cam on that disc. It will be seen that the entire apparatus



THE SINGER LADIES' BICYCLE.

for the production of the motive power is enclosed in the wheel. The arrangement is exceedingly compact, and the engine, while well protected from injury, is kept cool by the air currents set up by the arms of the wheel. The sides of the wheels are readily removable, but all parts of the engine, etc., are accessible through the openings between the arms. The engine is controlled by regulating the supply of the mixture of vapour and air, by varying the quality of the mixture, and by an exhaust-valve lifter. Obviously the only way of actuating these parts from the outside of the wheel is through the trunnions. Accordingly the one trunnion is traversed by a short spindle which



A. Carburetter with Filling Cap B and Discharge Tap C.
Q, P, O, M. Connections to Inlet Valve Chamber N.
I. Cylinder mounted on Crank Chamber E, to which the supporting Trunnions *d* are bolted.
J. Silencer.
T. Magneto Machine connected by Insulated Wire V to Sparking Plug L.
W. Interrupter Stem, the Foot Piece *k* of which engages the Cam *e*.
b. Exhaust-Valve Lifter, and *m* Supply Valve operated by the Levers *p*, *q*.

THE SINGER MOTOR WHEEL.

carries, inside the wheel, a lever for operating the supply valve and the exhaust-valve lifter, and, outside the frame, another lever which is coupled up to a handle on the handlebar of the machine. Similarly, through the opposite trunnion, passes a spindle for controlling the mixture valve. This trunnion is also fitted with a spindle for working the pump by which oil is charged into the crank chamber; both spindles are connected up to handles which may be operated from the saddle.

When fitted to a bicycle the motor wheel is placed behind; in a tricycle it is placed in front. The system lends itself very readily for application to ladies' machines; indeed it cannot be equalled by any other in that connection. The wheels for bicycles and tricycles for single riders are fitted with engines of two brake horse-power. The bicycles weigh about 110 pounds; the single tricycle is relatively a light machine, its weight amounting to 140 pounds.

Although their machines can travel at the rate of twenty-three miles an hour, the Singer Company do not profess to build racing machines; their object is to supply vehicles of entirely British manufacture, sound workmanship, suitable for ordinary road work, adapted to climb hills at fair speeds, and to travel long distances without breakdowns.

The Holden Motor Bicycle

This machine is built on special lines throughout and forms a quite distinct type. The rear wheel is driven direct by a four-cylinder horizontal engine, which is placed low down between the front and rear wheels, and is arranged to give an impulse for every half revolution. Two cylinders are placed on each side of the machine with their open ends facing each other and their pistons secured to the same rod, which is coupled at its mid-length by

means of a connecting rod to a crank on the rear wheel axle, so that no transmission gear whatever is required. The cylinders are cooled by water and the engine develops three horse-power; it is necessarily slow-running, the speed being about 500 revolutions per minute. The ignition is electric, and one coil is used for the four cylinders. Automatic lubricating devices are provided. No pedalling gear

THE HOLDEN MOTOR BICYCLE.

is employed, but convenient rests are fixed for the feet of the rider.

American Motor Bicycles

In the United States there is perhaps even more diversity of practice in the construction of motor bicycles than obtains in this country, and in some respects the development appears to be proceeding along different lines. For example, the use of dry batteries for the electric ignition, instead of accumulators, appears to be the rule, the surface carburetter is rarely used, and chain driving is more freely adopted. In regard to engine position several makers adopt the plan of building the engine into the

frame as part of the seat pillar, extending from the saddle down to the crank bracket. The Auto-bi, the Marsh, the Indian and the De Long bicycles are examples of this. In the Royal the engine is in the same position, but the seat pillar is divided into four branches, which embrace the engine and join at the crank bracket; the engine of this machine has hollow copper radiators brazed on the cylinder through which currents of air are supposed to pass. The Auto-bi has the petrol tank carried by the down tube, while the top tube itself forms the lubricating-oil reservoir. The engine fly wheel consists of a thin forging of large diameter. In the De Long machine the top tube of the frame forms the petrol reservoir.

The Orient bicycle, which has become pretty well known in England, has a frame of special design in which the engine is mounted in an inclined position. It is a high-powered machine, the engine being a two-and-a-half horse-power Aster, which drives by means of a flat belt, and is provided with a spray carburetter. The petrol tank is mounted over the rear wheel.

The Mitchell is another American machine which has become known in England. Like the Orient, it has a powerful engine, which in this case is mounted in the angle between the top bar and the inclined down tube of the frame, and secured to a saddle built into the down tube. The lubricating oil is fed continuously and automatically to the upper side of the cylinder.

The Merkel has the engine placed inside the frame parallel to the down tube, which, together with the seat pillar, is arranged to serve as a silencer.

The Keating, the Freyer & Miller, and the American Cycle Company's machines have the engine behind and parallel to the seat pillar. In the former the mud guard over the rear wheel is made hollow and adapted to serve as a silencer. The Freyer & Miller firm fit magneto ignition. The vertical arrangement of engines which appears to be growing in favour in England is not often met with in

American practice. The Stahl bicycle is, however, an example of that arrangement. It has the inclined down tube bent to form a loop which partly encloses the crank chamber.

Motor Tricycles and Quadricycles

After the survey which has been taken of the motor bicycle a very brief account will suffice for the tricycle and quadricycle.

The De Dion-Bouton tricycles and quadricycles are fitted with two-and-three-quarter horse-power vertical engines, which are mounted upon and drive the rear axles by gearing. The electric current for ignition is provided by a dry battery, and the switch for turning the current on and off is contained in one of the grips of the handlebar. A float-feed spray carburetter, of the kind used in the cars of the same makers, is now employed in place of the surface carburetter formerly used. A pump is fitted for forcing oil into the crank chamber, and two-speed gears and free engine clutches may be applied. The wheels are fitted with two-and-a-half-inch tyres.

The Enfield motor quadricycle is fitted with either a two-and-three-quarter or else a three-and-a-half horse-power De Dion-Bouton water-cooled engine and a spray carburetter.

The Century tandem tricycle more closely resembles a car in appearance, and is a far more powerful machine than the others, being fitted with a five horse-power Aster engine. This high power enables it to rush up hills at a great speed.

The Quadrant tricycle has a single driving wheel behind and two steering wheels in front. The machine is, in fact, identical with the bicycle of the same makers except for the front fork and wheels. The front wheels are carried on a crossbar and a system of levers and links

which allows the outer wheel to rise above the inner in describing a curve. The construction adopted gives a very light machine, the weight being about 100 pounds.

The Singer Company fit their motor wheel, already described, as the front wheel of a tricycle. The machine is built with a tandem extension either as a plain saddle, a basket chair facing rearwards, or a coach-built chair facing forwards, or they are convertible into carrier tricycles. Tricycles for single riders are fitted with two horse-power engines. For the tandem machines, and also for single machines intended for hilly districts or for heavy riders, two-and-a-half horse-power engines are used. The single tricycle weighs about 140 pounds.

CHAPTER XV

MODERN STEAM AND ELECTRIC CARRIAGES

COMPARED with the petrol car, the steam and electric carriages are as yet of but small importance—at least nine in ten of the motor cars in actual use are propelled by petrol motors—so although they present numerous interesting features upon which much might be written, it is not proposed to enter into their construction and action at any great length here.

Both steam and electric cars possess some decided advantages, and there can be little doubt that in their proper fields the application thereof will develop extensively. While they have not the wide radius of action which distinguishes the petrol car, the steam and electric cars possess motors which may be stopped and started with the greatest ease, and have a remarkable range of power and speed, and are thus independent of variable-speed gearing, they are silent in action and free from vibration, and they leave no objectionable odour behind them. The electric car is particularly cleanly and easy of management.

The steam car, however, requires, in addition to the motor, a steam generator or boiler with its attendant heating apparatus, and is often fitted with a condenser as well. It is under the necessity of carrying supplies both of fuel and water, and the consumption of fuel is more rapid than in the petrol engine. A liquid fuel, kerosene, or petrol, is usually employed. The petrol is the more easily vaporised and gives very little trouble,

whereas kerosene or ordinary lamp oil is a cheaper and more efficient fuel, but more difficult to burn properly. Several forms of kerosene burner have been devised, however, some of which answer the purpose admirably. Many of the cars are fitted with ingenious automatic arrangements for forcing the fuel and the water to the burner and the boiler respectively, in quantities proportioned to the steam consumption. The boilers are either of the "flash" or "instantaneous," or of the multitubular types; and the engines, except in the Serpollet and some other cars, are ordinary double-acting engines fitted with slide valves and link-reversing gear.

The Gardner-Serpollet Steam Cars

The early attempts of M. Serpollet in conection with road locomotion have been mentioned in a preceding chapter. It would be exceedingly interesting to trace out step by step M. Serpollet's subsequent progress, but considerations of space forbids this, and we must confine ourselves to a brief description[1] of the Gardner-Serpollet cars as they are now built at York by the British Power, Traction and Lighting Company.

There are many interesting points about these cars, but the distinguishing feature of the Serpollet system is the boiler or steam generator. In boilers of other types comparatively large volumes of steam and water are stored. In the Serpollet boiler there are no such stores. The water is supplied just in proportion to the momentary demand for steam, and is at once vaporised by contact with the heated metal of the boiler, just as a drop of water would be vaporised upon falling upon a red-hot metal plate; the action is almost instantaneous, and boilers of this type are

[1] The construction of the Gardner-Serpollet cars will be found described in great detail in a fully-illustrated series of articles in the *Automotor Journal* for June and July 1902.

termed "instantaneous" or "flash" boilers. In the early Serpollet boilers, when coke was the fuel employed, the boiler was composed of a nest of thick cast-iron tubes of C section. Now, liquid fuel is employed, and the boiler is composed of thin round tubes of steel. The tubes form a continuous passage, the water entering at one end and the steam escaping at the other; they are constructed in a series of sections, each composed of a piece of tube bent to and fro in zigzags, first in one direction and then in another

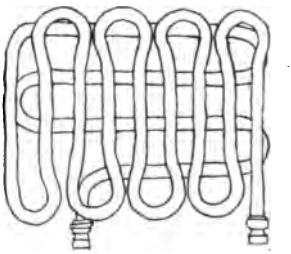
THE GARDNER-SERPOLLET STEAM CAR.

at right angles, so that each section resembles a piece of trellis; the sections are piled one above the other in a casing, their ends pass through the casing, and are connected up by coupling pieces.

The fuel is kerosene, ordinary lamp oil; it is supplied to a number of small burners, placed under the boiler, from a tank through a pipe which passes over the burners, where it is vaporised before it escapes. It is fed by means of a force pump, and in exact proportion to the quantity of water forced into the boiler by another pump, which is

under the control of the driver. For this purpose a very ingenious arrangement is employed, the plungers of the two pumps are connected at different points to a rocking lever, worked by the engine, the extent of the movement of which may be regulated by the driver, so that when the water supply is varied, the fuel supply is also varied proportionately.

It is clear that at starting when there is no flame above the burners some special means must be adopted for vaporising the kerosene; a dish of methylated spirits burned under the vaporising pipe, which extends over the burners, is usually used for this purpose. Similarly, when the engine is not working, hand pumps are required to force in the supplies of fuel and water. For the fuel, a small pump is used to force in air to the top of the tank, and for the water a hand pump. When the engine starts the automatic pumps come into action. A recent improvement, the "self-starter," has for its object to obviate the necessity of pumping the water by hand for starting. A vertical chamber is fitted with a piston, its lower end is connected to the boiler feed pipe, whereby the space below the piston is charged with water; that above the piston is charged with air under pressure. When the engine is stopped and the water connection closed by means of a valve, a volume of water is retained in the chamber. There is then available for the purpose of starting the engine a supply of water under the pressure of the air above the piston.



ONE OF THE TUBE SECTIONS, SERPOLLET BOILER.

Instead of the safety valve usually provided to prevent the steam from rising to an excessive pressure, the Serpollet boiler is fitted with a relief valve, which when opened forms a direct communication between the boiler and the feed-water tank; the pressure of the steam then forces the

water in the boiler back into the tank, and the generation of steam is arrested. The relief valve itself is opened by the steam pressure acting upon a little piston which is normally pressed down by a spring, but which when the steam pressure is strong enough to overcome the spring, rises and opens the valve.

The steam leaves the boiler in a highly superheated state, at a pressure of about 300 pounds per square inch, and it is used in a steam engine, much resembling the petrol engine in construction, and comprising four single-acting cylinders, *i.e.*, cylinders the pistons of which are under steam pressure on one side only. This construction has the advantage, for one thing, of not requiring a stuffing box for the piston rod to work through, and of thus dispensing with packing which is liable to be destroyed at high temperatures. The cylinders are arranged in pairs, on opposite sides of a crank shaft formed with two cranks at an angle of ninety degrees apart, two cylinders working on to each crank. The inlet and exhaust valves are poppet or mushroom valves, of the same kind as those used in the petrol engine; they are kept closed by the steam pressure and by springs, and are opened at the proper points in the stroke of the piston by means of cams. The cams are mounted on a shaft placed above, and geared to the crank shaft, and are so formed that by an endways movement the extent of the motion imparted to the inlet valves may be varied as well as the times at which they are opened. This enables the driver to vary the point in the piston stroke at which the supply of steam to the cylinders is cut off, to cut off the supply altogether, or to admit it so as to cause the engine to run in the opposite direction for reversing the car. A throttle valve controlled by a pedal is provided in the steam pipe.

The steam as it leaves the engine passes to an air-cooled tubular condenser, and is returned in the form of water to the feed-water tank.

Turning now to the general arrangement of the car;

the frame is of channel steel, the water tank constitutes the dashboard seen at the front, the boiler is at the extreme rear, and the engine is placed horizontally in the centre of the frame, and drives the rear axle by chain gear. The rear axle consists of a solid bar, running through both wheels, and of two tubular sleeves, to each of which are fixed one road wheel and one wheel of the differential gear; one of the sleeves is fixed to the solid bar, the other runs free.

The cars are made in six horse-power, twelve horse-power, and larger sizes, and with various types of body. The actual consumption of kerosene and water in the twelve horse-power car per ten miles run is stated to be one gallon of each, and the tanks are of sufficient capacity for a run of seventy-five to one hundred miles.

The Miesse car has, like the Serpollet, an "instantaneous" or "flash" boiler, but in this case it consists of a single coiled tube. The engine is a three-cylinder single-acting horizontal engine, it has mushroom valves operated by cams, and the exhaust valves are placed below the cylinders; the exhaust pipes lead to a condenser. The engine is geared to an intermediate shaft, which carries the differential gear and drives the rear wheels by a chain at each side of the car. In general appearance this car closely resembles the standard type of petrol car.

The House cars are worked by compound engines, the crank shaft of which drives the rear axle by spur gearing Provision is made for admitting high-pressure steam into the low-pressure cylinders when required. The boiler is of vertical multitubular type placed under the seat; the burner is adapted to burn kerosene. A condenser is fitted in the front of the car.

The Locomobile and other American Steam Cars

In the United States far more attention has been devoted to the application of steam as a motive power for passenger carriages than in Great Britain, and the light American steam cars have by their silence and smooth running secured a large amount of favourable consideration in this country, where the Locomobile in particular has become very popular.

THE LOCOMOBILE TOURING CAR.

Like most American cars the Locomobile is propelled by a two-cylinder double-acting engine of ordinary construction fitted with a slide valve and a link-reversing motion such as are used in the locomotive. The engine drives the rear axle by means of a chain which runs over a wheel on the crank shaft and over another on the differential gear casing. There is, in addition to a throttle valve in the steam pipe for regulating the supply of steam to the engine, a stop valve which may be used to cut it off entirely; the

handle of this valve may then be removed, so that the car cannot be started by a person not in possession of the handle.

The steam is supplied at a pressure of 180 pounds per square inch from a vertical tubular boiler composed of a plain cylindrical steel drum, wrapped with piano wire to increase the resistance of the shell to rupture, and of a large number (300 in the sixteen-inch boiler) of small copper tubes which traverse the drum from top to bottom, and through which the flame from the burner passes upwards to a smoke box placed over the top of the drum. The products of combustion escape downwards from the smoke box and are discharged under the car. The fuel is petrol; it is stored in a tank and is forced to the burner by air pressure, the upper end of the tank being in communication with a reservoir of compressed air, kept charged by a hand pump. The burner consists of a shallow round box somewhat smaller in diameter than the boiler, and placed just below it; the box is traversed by a series of small tubes through which the air for the combustion of the petrol ascends; through the side of the box another tube of larger diameter penetrates, this is open at both ends and the nozzle of the petrol pipe fits into the outer end; the nozzle is smaller than the tube, and through the space between them air is drawn in by the inrush of petrol vapour. The petrol must, in order to ensure perfect combustion and freedom from smoke, be vaporised before it reaches the burner, and for this purpose the petrol pipe is led through the boiler, the heat of which effects the vaporisation. For starting the burner, a section of the pipe is heated by a torch; this plan is found to be efficient, and it is simple and safe. The time taken to get up steam and start the car, the boiler being cold at the commencement, is six minutes. The vapour escapes from the box of the burner by a number of minute perforations made in its top, around each of the air tubes, and at once

mixes with the air passing up through them and burns with a solid blue flame above the top of the box. The supply of fuel is regulated automatically in accordance with the pressure of steam in the boiler. The water is forced from the tank to the boiler by means of a pump worked by the engine itself; a hand pump is provided for use in starting or when the engine is not working, and an auxiliary steam pump may also be fitted. The water pipe is led, in the form of a coil, through an exhaust box or silencer, through which the exhaust steam from the engine is discharged, with the object of heating it before it enters the boiler and thereby economising fuel. In some cases the steam is discharged into an air-cooled tubular condenser.

It might be supposed that trouble would arise from the choking up of the boiler tubes, by matter deposited by the water, but in practice it is found that this is entirely avoided by a periodical blowing out of the contents of the boiler.

As to general arrangement, the petrol tank is placed under the footboard, the engine under the seat, and the boiler between the engine and the water tank, which is at the rear of the car. The frame is composed of tubes. The steering is effected by a lever at the side of the car, and the front wheels are pivoted on the Ackermann system. The differential gear on the rear axle is composed of spur wheels, and is enclosed in a casing charged with grease. The transmission gearing being a single chain is not liable to injury from mud and dust.

The Locomobile cars have been considerably strengthened and improved within the last two years, and are now very reliable machines.

The ordinary two-seated car appears to be one well adapted for the use of medical men. Cars of that description carry supplies of fuel and water sufficient for running about forty-five and thirty miles respectively; the four-seated cars for touring, etc., carry supplies for about double those distances.

In the Weston cars, the starting of the burner is affected by a "pilot light," and the makers make a strong point of "start it with a match." A small quantity of petrol is run into a dish, ignited by a match, and allowed to burn under a tube; this is rapidly heated, petrol is then run through the pipe and becomes vaporised; the issuing jet of vapour is ignited by the flame of the petrol

THE WESTON STEAM CAR.

in the dish and plays upon the vaporising section of the main petrol pipe, which extends across the burners, and heats it until it reaches a sufficiently high temperature to vaporise the petrol. The main supply is then turned on, and the vapour issuing from the burner catches fire from the pilot light. The fuel feed is regulated by hand. The pilot light is kept burning constantly, so that the main supply may be turned off and on as required.

The main supply and that to the "pilot" light are quite distinct.

Another point about the Weston car is the water lift, by which the water is sucked up from any convenient

WESTON CAR, WITH WATER LIFT IN OPERATION.

source direct to the tank without the use of buckets, etc.

The eccentrics and the chain wheel are forged in one solid piece. A very convenient tool cabinet is fitted in the rear of the car.

The Reading car is propelled by a four-cylinder single-acting engine, to which steam in distributed by a single

rotary valve in the centre. The burner is started by burning methylated spirits under a small coil, and a steam blast is fitted for use when required. A condenser is carried under the rear axle.

The White car has a "flash" boiler consisting of a coiled tube; the water is supplied at the top and the steam escapes at the bottom. The fuel supply is regulated by a thermostat according to the temperature of the steam, and the water supply by a diaphragm regulator according to the pressure in the boiler.

Electric Carriages

The electric car requires a motor or motors, a controller for regulating the distribution to the parts of the motor of the electric current, and an electric accumulator or storage battery, for it must be remembered that all modern electric cars work on the storage system. The motors and controlling arrangements have been brought to a high pitch of perfection, but the storage battery cannot be said to have reached an altogether satisfactory state as yet, in spite of the immense amount of labour which has been expended upon it. These appliances are largely used in electric lighting stations for storing the electrical energy produced during the day, when the demand for lighting purposes is small, and giving it off at night, when it is greatly increased. They allow of the machinery being worked constantly, and thus more efficiently, and enable a smaller generating plant to be used than would otherwise be the case. Even here, however, where they work under the most favourable conditions and under constant expert supervision, and where weight and bulk is no particular objection, it cannot be said that storage batteries are looked upon as a perfect success.

In the motor car the conditions are quite the reverse of favourable; weight in proportion to storage capacity is

a consideration of the first importance; the batteries do not, in the hands of the ordinary user, receive that constant supervision which obtains in the lighting station, and is essential to their well-being; and the vibration of the car, due to the inequalities of the roads, and the sudden variations in the demands upon the battery, incidental to motor car work, exert a very injurious effect upon the texture of the plates, causing the pasted material, with which they are filled, to disintegrate and fall into the acid solution in the cell. Some of the loosened material no doubt remains in suspension, the rest falls to the bottom of the cell, where it accumulates and, bridging the space between adjoining plates, causes the short circuiting of the current. This last difficulty has to some extent been met by resting the plates on ridges, so that they stand above the bottom of the cell, leaving a free space into which the deposited material may drop. There is no doubt whatever that immense improvements have been effected in the existing types of storage batteries, in regard to the reduction of weight for a given capacity, to durability as well as in efficiency; but it almost seems that the future success of the electric car depends upon the invention of some radically new method of storing electrical energy. The nickel-iron battery of Mr Edison has been much talked of recently, and it may yet be found to yield a satisfactory solution of the problem, but so far it does not appear to excel either in capacity or in the durability of the elements some of the existing types of batteries. To enter into a discussion upon the various types of storage battery and the comparative merits of the different types of motor employed would take us far beyond the limits allowable here, and it must suffice to say that the storage battery consists of a number of elements, composed of specially-prepared metal plates, which, upon the passage of an electric current from a dynamo or other suitable source—"charging"—undergo a chemical change. In this condition they are prepared to revert to their original state,

when their terminals are connected up by a metallic circuit, producing, in so doing, an electric current in that circuit. This current is converted into mechanical energy by means of an electric motor, which is to all intents and purposes a dynamo working in a reverse direction, and the shaft of the motor is coupled to the wheels of the car either directly or through a train of gearing which may be used to reduce its speed. The speed and direction of rotation of, and the power given off by, the motor can be varied by changing the path of the current through the armature and field coils of the motor, and by changing the grouping of the cells of the battery. This is effected by means of the controller which has a movable piece provided with a series of contacts adapted to connect corresponding terminals according to the position of the controller, and thus to send the current along the required path.

When driven by a single motor the car must be provided with a differential gear for transmitting the motion to the wheels, in order that they may run at different speeds when required. When each wheel is provided with a separate motor, as is frequently the case, the differential gear is dispensed with. One large motor, however, is more efficient, *i.e.*, produces a larger amount of mechanical energy for a given consumption of electrical energy than two small ones. Still the balance of advantage appears to lie with the system of using two separate motors. Another point that may be mentioned is that in going downhill the car may be arranged to drive the motor, this then becomes a dynamo and sends a current into the battery. The charge thus imparted may not be very great, but it seems to have a material effect in prolonging the life of the battery. The absorption of the energy of the moving car in this way by the motor has the effect of a brake in reducing its speed. Having thus very briefly indicated the leading features, we may now proceed to a short outline of a few modern electric vehicles.

The coach of the Accumulator Industries of Woking, with seats for twelve persons, is the largest electrical carriage in this country. From a recent account[1] it appears that the vehicle is provided with Leitner accumulators consisting of forty-four cells, each of 500 ampère[2]-hours capacity, and two Lundell motors, which are geared independently to wheels secured to the rear road wheels. The motors are mounted on the rear axle by means of springs, and normally each gives off seven-and-a-half horse-power, but it may be worked up to fifteen horse power. The motors are separately excited, and each has two armatures, which by means of the controller can be placed in series, in parallel or in multiple, according to the speeds required. The coach can attain a speed of upwards of twenty miles an hour. The battery capacity is sufficient for a run of eighty miles.

The City and Suburban Electric Carriage Company have done much to bring electric carriages into favour in England. In addition to building and selling carriages, they have arranged a scheme for housing and keeping them in order afterwards. For a fixed monthly payment they undertake the housing of the carriage, the charging of the batteries, the adjustment of the parts, the inspection and care of the batteries, the washing of the carriage, and the lubrication of the motor and gearing, all under expert supervision, as well as insurance against damage to the carriage, or caused by the carriage to persons on the road, and against fire while on their premises. For an additional charge the renewal of the batteries, the solid rubber tyres, and all working parts is undertaken. Of course this

[1] *The Automotor Journal*, June 7, 1902.

[2] The *ampère* is the measure of quantity of current. This battery would give off a current of 50 ampères for one hour, or 2500 for two hours, etc.

The *volt* is the measure of the pressure of the current. The pressure of the ordinary storage cell when charged is somewhat over two volts. The quantity of current multiplied by its pressure gives the power of the current; it is expressed in *watts*. *Ampères* × *volts* = watts. A current of one ampère at a pressure of one volt flowing for one hour equals one watt-hour. The watt is a relatively small unit of power, being equal only to the $\frac{1}{746}$th part of one horse-power.

ELECTRIC FOUR-SEATED LANDAULETTE, 1902. THE CITY AND SUBURBAN ELECTRIC CARRIAGE COMPANY.

arrangement only applies to carriages within a convenient distance from their *garage* in London, but already the scheme has been taken up to a considerable extent and a number of their carriages are in use in London. There are besides many in the country. By this scheme the necessary constant supervision of the batteries by experts is ensured, and the owner of the carriage is relieved of all trouble in regard to the motive power. The carriage bodies are built in a variety of styles, the landaulette being a favourite for town use. The carriage is mounted on a rectangular tubular frame, to the rear member of which are pivoted two motors, one for each rear wheel. The motors are of two and a half horse-power each and drive the wheels by toothed gearing. The battery capacity of the ordinary carriages is sufficient for a run of about forty miles, on a dry, level road, with a maximum speed of twelve miles per hour. The touring phæton has a 300 ampère-hour, ninety-six cell battery, of a capacity for about 100 miles at thirteen miles per hour.

Mr Carl Oppermann has made a number of successful electric carriages. His mail van has been in use by the Post Office authorities for some time, and has run over 1000 miles, made up in daily journeys of thirty-three miles. So far, it is said, there has been no trouble whatever with batteries, motor or gearing. The car is fitted with a three horse-power motor, and a battery of forty cells of 160 ampère-hours capacity. The motor is connected by spur gearing to a transverse shaft, carrying the differential gearing from which the rear wheels are driven by chains. The controller is arranged to group the cells, etc., to give two speeds and a reverse. One of the features of the ordinary carriages of this maker is the use of worm gearing for transmitting the power from the motor to the differential gearing.

A special accumulator is used, of which the discharge is said to be twenty-two ampères for nine hours, and the

weight twenty-four pounds; this gives a capacity nearly 1·7 watt-hours per pound of cell.

That it is possible to make long journeys with an electric carriage was established by the run made in 1901 by the "Powerful" of the British and Foreign Electric Vehicle Company. Between May 25 and July 30 this car covered over 1837 miles with the same, Leitner, battery. Four persons were carried throughout the run, and sometimes one more was taken up.

The British Electromobile Company this year ran a car from London out on the Bath Road over ninety-seven miles with a single charge of the batteries, which were composed of forty-four Leitner light traction cells of 300 ampère-hours capacity. It was intended to demonstrate that 100 miles could be run on a single charge, and no doubt this might have been done, but for the fact that owing to heavy rain the roads became very slippery. On the good and fairly level road from London to Maidenhead the current consumption averaged about twenty ampères; on the hilly section from Maidenhead to Reading it was doubled. This car was constructed on the Krieger system, with front driving wheels each provided with a separate motor.

It is much to be regretted that the electric vehicle trial arranged this year by the Automobile Club fell through from lack of competitors. It can hardly be said that the conditions of the competition were too onerous.

It has been stated that all modern electric vehicles are worked on the storage system; it is worth noting, however, that they may be worked without storage or other batteries, by the overhead wire and trolley system, so well known in connection with electric tramways. An instance of this is to be found at Konigstein, in the valley of the Biela, a tributary of the Elbe, in the Saxon Switzerland. A suggestion to this effect was thrown out in *The Electrical Review* in 1894, and in 1897 such a plan was being tried in America.

CHAPTER XVI

MOTOR WAGONS AND VANS

Up to the present the passenger vehicle has occupied the attention of the public almost to the entire exclusion of the motor-propelled vehicle for the transport of goods, but nevertheless the latter is making steady headway and quite a large number of them are already in use, while several firms have taken up their manufacture in this country. For light work, such as the delivery of parcels from stores and shops, a van body is built on the frame of an ordinary petrol car, the gearing being altered to suit the speed required and the load to be carried. For heavy work, in England at anyrate, the engineers who have taken up the matter have considered the steam engine the most suitable motor. Wagons or lorries propelled by explosion engines are, however, being made in Germany and have given good results. Such a machine was entered by Messrs Milnes & Company for the War Office trials in 1901, and although this particular vehicle did not comply with the requirements laid down, its performance was such as to suggest further trials in this direction. In their report on these trials the Committee of judges state that they consider that the oil engine gives great promise for the future, owing to its very small consumption of fuel, and almost complete independence of water supply. Although the competing engine was underpowered for the prescribed load, it served to demonstrate that a lorry of a type required for military purposes could attain a large radius of action when using heavy oil. The engine required to be run for about ten

minutes with petrol before the vaporiser was sufficiently heated to allow of the heavy oil being used. This is regarded as a defect to be remedied. With forty gallons of oil, heavy Russian petroleum, the car had a radius of action of 145 miles when loaded with three tons. The consumption of water was only about one-thirtieth of a gallon per mile. On the sixth day of the trial this car made a non-stop run of thirty-two and three-quarter miles in four hours fifty-six minutes, carrying a load of three tons. This gives an average speed of 6·64 miles per hour.

THE MILNES PETROLEUM WAGON.—The motor is a four-cylinder oil engine, the diameter of piston being ninety mm. and the stroke 120 mm. It is built on the Daimler principle throughout, with Daimler float feed, governor, and water cooler. The number of revolutions per minute is 750, and the brake horse-power is twenty-five. Lubrication is by automatic pressure to all engine bearings; water circulation by a gear-driven rotary pump. The fuel is fed by pressure from a portion of the exhaust. The ignition is by the Simms-Bosch magneto-electric system.

The transmission is by a single friction clutch. The power is transmitted from the main longitudinal shaft through the differential gear by means of two pinions engaging two internally-toothed wheels fixed to the back road wheels. The speed-changing gear is on the Cannstatt system, four speeds being provided. With this gear, the first and second and third and fourth speeds are each controlled by one lever, by which means, as the two couples of speeds are independent of each other when changing, neither couple affects the other set of gear wheels. The Cannstatt principle for changing speed also automatically disengages the friction clutch when either speed lever is actuated. The reverse speed is obtained by dropping into gear a special cog wheel.

Turning to the steam wagons, the arrangement most favoured is to mount a vertical boiler over the front

steering-axle, and to place the driving wheels under the body of the vehicle. The engine is in some instances under the body of the wagon, and in others placed in front with the boiler.

The THORNYCROFT steam wagon of the standard type is capable of carrying three tons, and drawing a further two tons on a trailing vehicle; it is fitted in front with a central-fired water-tube boiler, specially arranged for cleaning the internal surfaces, a most important feature when, as is frequently the case, hard water only can be obtained. The engine is compound, and fitted with piston valves provided with rings; it is placed under the body of the wagon, is entirely enclosed in a dust-proof and oil-tight case, and is fitted with a radial valve gear; the gearing is of machine-cut steel, and drives the road wheels by means of a spring-driving apparatus, which prevents the transmission of the road shocks to the gearing. The springs are of the semi-elliptic pattern, the front axle being mounted so as to give the frame a three-point support to avoid all twisting strains when the wagon is going over rough and uneven ground. Steering is effected by worm gearing, the axle being of the double-hinged pattern. One man is able to perform easily all the operations required in driving and controlling the vehicle. It is fitted with a steam brake capable of stopping the wagon in its own length when running at full speed. A steam jack and water lifter are provided in the equipment. Solid or liquid fuel can be used, the bunkers having a capacity sufficient for fifty miles.

The differential gear may be locked by a friction braking device, which the attendant can apply without getting underneath the vehicle.

In another type of wagon, specially adapted for use on rough roads and uneven ground, the steering axle is capable of an unusually great angle of tilt, and the driving and steering wheels are of large diameter. The boiler and engine are situated directly over the driving axle, the

carrying platform being in front. This arrangement gives the wagon greater power to get out of holes in soft ground, etc., and enables it to exert its full power as a tractor when it is not itself laden. The boiler and engine are of the same pattern as in the standard wagon; and the boiler is arranged so that the fire bars can be easily replaced by the liquid fuel burners.

A condenser is provided, but is arranged so that it can be short-circuited or removed without interfering with other parts of the machinery. The boiler is fed by a pump driven from the engine, or by an auxiliary pump or an injector. An exhaust feed-water heater is also provided.

The Leyland, Coulthard, Clarkson-Capel and Straker steam wagons are built on the same general plan, but each has characteristic differences in detail; the first three, for instance, are fitted with condensers for the exhaust steam, and they all use chain gearing in conjunction with toothed gearing for transmitting the power of the engine to the wheels or axle, whereas the Thornycroft has tooth gearing only.

The Musker wagon has a special form of coil tube boiler, fired by oil and placed under the body of the vehicle, and an auxiliary engine to supply oil and air to the burner and water to the boiler.

The Simpson-Bodman has a flash or instantaneous boiler, and separate three-cylinder engines for each wheel.

A departure from the general type is found in the Foden steam wagon. It consists of a small traction engine combined with a wagon. The wagon is placed behind the engine and connected to it by a steel frame of channel section. The driving wheels are placed under the wagon and are driven by a two-speed spur gear and chains. The boiler is of the locomotive type, and the engine, a horizontal compound, is mounted on top of it. The wheels have cast-steel hubs and disc sides, formed of steel plates.

The Mann steam cart likewise consists of a combination of a traction engine and wagon.

On the vital question of the cost of working motor wagons some instructive figures are given in a paper by Professor H. S. Hele-Shaw.[1] A Leyland wagon, in use by the Liverpool Corporation, was tested by Mr Brodie, the City Engineer, against horse wagons on a working journey of three miles, returning empty. The cost of the steam wagon worked out at 6¼d. per ton-mile; that of horse haulage at 10d. In a week in March 1899 the wagon carrying four-ton loads a distance of three miles and returning empty cost 7¾d. per ton-mile. In another week in October, doing similar work, but over a somewhat longer distance, the cost was 8¾d. Mr Brodie points out that where the haulage distance is less than two miles, the advantage of the motor wagon is much reduced. He gives the cost of twelve months working, including wages, maintenance, repairs, and £1 per week for depreciation, as £243, 14s. 8d.

Another Leyland wagon employed by the Mersey Docks and Harbour Board for general use in connection with the dock establishment for conveying materials from one part to another is stated by Mr Lyster, the Engineer-in-Chief, to be much cheaper than the horses formerly used, and as "regards despatch and convenience, which are often of greater importance in urgent work than direct cost of transport, the comparison is immensely in favour of the motor vehicle."

In the case of a Thornycroft steam wagon and trailer, in use by Messrs Fuller & Company, the total cost, inclusive of interest, depreciation, wages, fuel, adjustments and repairs, and stores, taken over a period of fifteen months, works out at 3·4d. per ton-mile. Another Thornycroft steam wagon, employed at Liverpool by the Lancashire and Yorkshire Railway for town delivery of goods, has been found particularly useful in taking loads of about three tons on journeys, where, owing to stiff gradients over a portion of the road, two horses would ordinarily have had to be sent.

[1] Proceedings of the Institution of Mechanical Engineers, April 1900.

The Liverpool Trials 1901

The Liverpool Self-propelled Traffic Association have done a considerable amount of valuable work in promoting the improvement and extending the use of motor wagons, and the report of the trials conducted under their direction in June 1901 contains a mass of important information on the subject. In their report, speaking of the capabilities of the motor wagon, the judges say:—

"The performance in ton-miles per working day depends very largely on the facility with which loading and unloading can be carried out. In good weather a motor vehicle can average five miles an hour on the road, which, in a shift of twelve hours, leaves four hours for meals and the collection and delivery of goods with a journey of forty miles between the terminal points. In wet weather, and during portions of the winter, it will be advisable to reduce the speed or load according to circumstances.

"We are of opinion that the three components of transport work, viz., collection, convey, and delivery, may generally, where the total mileage does not exceed forty-five miles, be completed within twelve hours."

And as to cost of repairs and adjustments:—

"Taking into consideration the imperfections of common roads, and the fact that users will take advantage of any structural improvements in the vehicles by working them harder than before, we think it will be necessary, apart from accidents of an exceptional nature, to allow not less than £75 per annum per vehicle for repairs and adjustments, when working a single shift of twelve hours per day, even where the mileage is regulated with discrimination according to the roads travelled over."

These trials confirmed previous trials in regard to the ability of the motor wagons to start and stop both up and down hill on a gradient of one in nine, with the improvement that every vehicle possessed sufficient adhesion to

start promptly from rest, laden or unladen, and it appears that short rises of one in eight were climbed without difficulty with full load.

"The powers of control possessed by the driver of a motor vehicle are particularly evident in manœuvring, and on hills, and are superior to those exhibited by the best types of horse-drawn vehicles. In descending steep hills, the normal speed can be maintained without locking a wheel or using a slipper.

"The fact that a motor vehicle can travel backwards with great facility will prove of considerable advantage for entering and leaving many loading-ways, as compared with a horse-drawn vehicle, the capacity of which for backing and manœuvring is limited by the strength of the shaft horse and the skill of the driver in securing the leverage obtained by moving the forecarriage about one wheel as a centre."

As to risk of fire or the possibility of creating a nuisance, the judges state that:—

"No risk of fire need attach to a motor vehicle by reason of discharges from the fire by the funnel, as the effective baffling of sparks, small cinders, and dust has been accomplished without interference with combustion. No nuisance need arise from the blowing-off of steam, as the fire is under control while standing from other causes."

The difficulty of making wheels of suitable design and strength to stand the work is alluded to:—

"Although the design of the driving wheels, which gave rise to the principal troubles in 1898, is now such as to render them structurally efficient, signs of undue stress, the results of the heavy shocks and vibration experienced on sets and rough roads, were not altogether wanting in the spokes and felloes of some of the wheels, which indicates that some practical means of absorbing these shocks is desirable."

Two vehicles propelled by petrol engines were tried:—

"They behaved satisfactorily in all respects, and their

chief drawback is the heavy cost of fuel per ton-mile compared with that for solid fuel in a steam-propelled vehicle. But where ability to travel considerable distances at average speeds of from six to eight miles an hour, with loads not exceeding two tons, is a factor in determining the motive power to be adapted, the higher cost of fuel may be more than compensated for. These vehicles were not seen to the best advantage during the trials, as they were held back at intermediate depots to let the heavier vehicles catch up.

"When internal combustion engines can use ordinary mineral oil, petroleum or paraffin, under the varying conditions imposed by road locomotion, without creating a nuisance, their wide adoption is assured, because the cost of fuel will then come within the range of commercial conditions for road transport."

Finally, in regard to the regulations as to the weight of the unladen vehicle and the width of the tyres, the judges "point out that the damage to road surfaces, commonly alleged as an objection to the increase of axle-load, cannot occur when the width of tyres is in proportion to the load upon them, and further that the increase of load on wheels with a corresponding increase in width is, on the contrary, of direct benefit to the roads, as is demonstrated by the action of the ordinary steam roller.

"The present tare limit of three tons has again proved to be too low if loads of above five tons are to be dealt with, even under favourable conditions, upon a single platform. Whilst one of the competing vehicles carried as much as five tons during the trials, with a tare weight of slightly less than three tons, this load will be excessive for the same vehicle in winter or wet weather, and an average load of four tons is probably the most that can be carried regularly having due regard to the life of the machine. Such a vehicle could also haul three tons on a trailer, under favourable conditions, in addition to the load of four tons carried on its own platform."

The War Office Trials

An important series of trials were carried out at Aldershot in December 1901, having for their object to determine the best form of motor lorry for military purposes. Among the requirements specified were the carrying of a load of five tons, three on the motor wagon itself and two on a trailing wagon, at an average speed of at least five miles an hour on average roads up and down hill, and the capability of ascending hills of one in eight without assistance, and with full loads. The firms of Thornycroft, Foden and Straker sent in steam wagons, and that of Milnes a wagon propelled by a petroleum engine. After an inspection of the competing vehicles, there was a two days' trial of about thirty miles each day with full loads; then a day's rest, for overhaul and inspection, followed by a march of 197 miles carried out on six consecutive days, on roads specially selected for hills, including two passages over the Hog's Back, where the steepest gradient was 1 in 7·2, the ascent of Hindhead and others, and—finally—rough country trials with full loads over a selected piece of ground in the Long Valley, where streams with steep approaches and a stretch of boggy ground had to be crossed. At the conclusion of the trials the condition of the engines and boilers was carefully examined.

It is needless to say that all the vehicles did not escape unscathed from this severe test, but the Committee report that it was demonstrated that the full load of five tons could be transported over thirty miles of hilly road in five hours, and that greater speeds could be attained for short distances, and further, that the steam lorries are good and serviceable machines suitable for present supply, and likely to be of great advantage to the transport service in countries where fuel and water in sufficient quantity are available. They point out that the load transported by each single lorry, five tons, if carried in horse wagons,

would require twelve draught horses besides riding horses, whose pace would not ordinarily exceed three miles an hour, and that the marching of 197 miles in six consecutive days would have necessitated the use of spare horses. As a result of the experience gained at these trials, they consider that for handy and rapid work, work of distribution among troops and near the front of an army, a lorry without a trailer is preferable, but that for moving stores in large quantities a powerful engine hauling a train of wagons is most suitable.

The whole of the roads travelled over were carefully inspected by the local road surveyors, accompanied by a surveyor acting on behalf of the War Office, immediately before and immediately after the road trials. In spite of the winter season, and weather alternating between frost, thaw and heavy rain, it was found that no damage whatever was done by the vehicles to the road surfaces, although some portions of the roads were traversed no less than ten times. The Committee accordingly "call special attention to the demonstration afforded by these trials of the entire harmlessness to roads of vehicles considerably exceeding in weight and road-speed the limits allowed by the present regulations on the subject, and also fitted with wheels to which road strips have been fixed, so long as these wheels are of large diameter and have tyres of considerable width. It has now been proved that the existing regulations are unnecessarily restrictive, whilst they stand in the way of the development of a most important method of transport and branch of industry."

CHAPTER XVII

GEARING, BRAKES, TYRES, HORSE-POWER

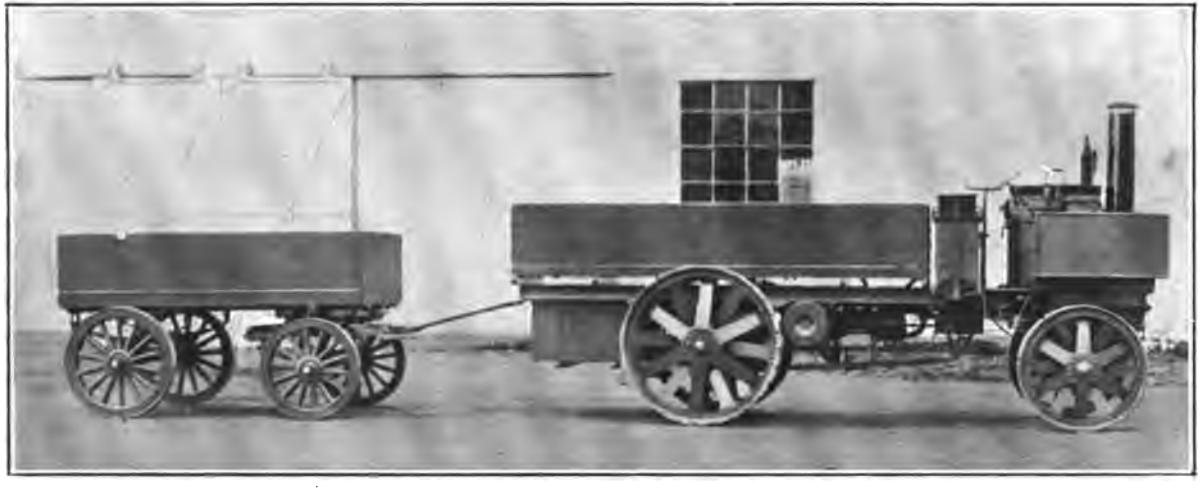
ONE of the most important considerations in the design of a motor vehicle is the transmission of the power of the motor to the driving wheels. In the case of the locomotive this is effected in a very simple and direct manner; the cranks of the engine are either fixed in the wheels or are formed in the axle upon which they are secured, and the pressure exerted upon the pistons is transmitted to them directly by the piston rods and connecting rods.

In the motor car, however, except perhaps in the case of a rotary motor, such as an electric motor, this simple solution of the problem is not admissible. The strains to which the driving axle is subjected, in consequence of the inequalities of the road surface, are such that it is inexpedient to weaken it by the formation of cranks therein, and the consideration of the width of the machine is alone sufficient to veto the idea of driving by means of outside engines and crank pins on the wheels. Still it is not impossible to drive cars in this way, and in fact steam cars have been so made, some with cranked axles and others with outside engines. Another consideration that presents itself is that with direct driving the speed of the engine is necessarily the same as that of the wheels, so that the engine must be larger and heavier to develop the required power than would be the case if it ran at a higher speed, and further, the power exerted upon the piston bears a constant ratio to that given off at the peripheries of the wheels, so that the engine has to be big enough to over-

come the highest resistance to be encountered by the wheels, and hence far too big for normal work. The steam engine, it is true, does lend itself to a considerable variation in the power developed, and the petrol engine also has become far more amenable in this direction than it was formerly, but certainly as matters now present themselves it is desirable, if not essential, to have an arrangement which will allow the engine to run at a higher speed than the driving wheels, and permit of their relative speeds being varied. Beyond this again is the question of the relative positions of the motor and driving wheels in the car, the accessibility of the engine and gearing for inspection and repair, the proper distribution of the weight upon the driving and steering wheels, and the movements or vibrations set up by the action of the reciprocating engine.

The standard practice now is to drive the rear road wheels by an engine placed in the front of the car. It is required then to transmit the rotary motion of a shaft at one end of the car to the driving axle or to the wheels themselves at the other end. For this purpose there are available the various systems of mechanical gearing in common use, *i.e.*, toothed, chain, belt, and friction gearing. The use of links and ratchets and pawls has also been proposed, but for various reasons this system is not likely to come into general use and it need not be considered here. Each of these systems has its advantages and disadvantages, and the problem is to find out that system or combination best adapted for the conditions of the case. For the benefit of non-technical readers it may be well to explain briefly the nature of these systems of gearing; a knowledge of the terms employed and their meaning will greatly facilitate the understanding of the descriptions of the various cars.

In *toothed gearing*, taking first the case of *spur gearing*, which is used to connect two parallel shafts, axles or spindles, a wheel on one shaft with a number of teeth all of the same size and shape, radiating from its periphery



THE THORNYCROFT STANDARD STEAM WAGON, WITH TRAILER.

and separated by spaces slightly wider than the teeth at their mid height, engages with a corresponding wheel on the other shaft, the teeth of the one entering the spaces between the teeth of the other; thus one wheel cannot turn without taking the other with it. It is clear that the two wheels must move at the same peripheral speed, and that if one has twice as big a periphery as the other it will have made one complete turn while the other has made two, and generally the relative number of revolutions of the two shafts, or their velocity ratio is inversely proportioned to the extent of their peripheries, or, what are the same things, to the number of teeth and the diameters of the wheels. The diameter is measured at the pitch circle, a circle somewhat larger in radius than the mean of the radii of the tops and bottoms of the teeth. Where they gear together the peripheries of two such wheels move in the same direction; their rotation is therefore in the opposite direction, *i.e.*, their upper surfaces, for instance, move in opposite directions. To obtain movement in the same direction, a third wheel must be introduced, and the wheels on the shafts, instead of gearing together directly, each gear with the third wheel. This has simply the effect of changing the direction of rotation of the driven wheel and has no effect upon the velocity ratio. When the shafts to be connected are inclined instead of being parallel to each other *bevel wheels* are used, *i.e.*, the teeth are made, tapering, upon the surfaces of cones; the action is precisely the same as that described above. The teeth of both spur and bevel wheels may extend across their faces at right angles to the sides, as is the common practice, or, with the object of attaining greater smoothness in working, they may be inclined to the sides. The inclined teeth are really parts of screw threads, and upon a wheel with a sufficiently wide face each would make a complete convolution. This construction constitutes *screw* or *helical gearing*, and it may be used to connect shafts which are inclined to each other but which lie in parallel planes;

the *worm and wheel* is a particular case of such gearing.

In *friction gearing* the transmission is effected by the direct contact of one wheel with another, but here the positive action of the teeth of toothed gearing is replaced by frictional adhesion due to the wheels being held one against the other with sufficient pressure to transmit the required power. To increase the efficiency one of the wheels may be made of, or lined, with leather, paper or other material adapted to increase the friction. Here again parallel or inclined shafts may be connected by the use of cylindrical and conical wheels respectively, and in addition, a variable-speed arrangement, which seems to have a great attraction to embryo motor-car builders, may be arranged. A small roller on a spindle is pressed against the flat face of a disc secured to a shaft at right angles to the spindle and is rotated by contact; by making this roller movable along the spindle the speed imparted to it may be varied; when it is opposite the centre of the disc it remains stationary, as it is moved towards the periphery its speed increases; by arranging for it to be moved on opposite sides of the centre of the disc, the roller may be rotated in the reverse direction. This is a pretty combination, and is found useful in some kinds of light machinery, but it is not adapted for power transmission in a motor car, nor indeed is any form of friction gearing. (2) Lambert, Carter car, Waltham Orient, &c.

From friction gearing the natural step is to another non-positive transmission, *belt* or *rope gearing*. Here the plain surface wheels or pulleys, instead of bearing directly one upon the other, are placed at some distance apart, and are both embraced by an endless band under some degree of tension. As the driving pulley rotates, the belt which clings tightly to it is carried round, one side is tightened, and pulls round the driven pulley. To make this combination positive in action the plain pulleys are replaced by wheels with teeth which are embraced by an endless

chain having links adapted to engage with the teeth; this constitutes *chain gearing.*

In both cases the velocities are, as in the case of toothed gearing, inversely proportional to the diameters of the pulleys or wheels, but the direction of rotation is the same in the driving and driven wheels, and is not, as with direct gearing, reversed. Reversed rotation may be obtained, however, by crossing the band, *i.e.*, leading it off the top of one pulley on to the bottom of the other instead of straight across from the top of one to the top of the other.

The wheel gearing described is employed for transmitting motion from one rotating shaft to another, not in the same axis with it. In order to couple two shafts or other rotating parts which are in line with one another *clutches* and *couplings* are employed. Clutches are intended to allow of the disengagement of the parts when desired; they are made in two main types, *claw*, or *positive*, and *frictional.* In either case there is one member fixed to its shaft, and another capable of sliding but not of rotating upon its shaft. In the claw clutch these members take the form of discs with claws or projections, which, when the sliding disc is moved into contact with the other, mutually engage and transmit the motion; upon moving the sliding disc away, the transmission is arrested. In the friction clutch the two members have plain faces, and are pressed together to produce the required degree of grip to transmit the power; one or both parts may be faced with leather or some such substance to increase the friction. There are a great many types of friction clutch. A clutch of the *cone* friction type is used in the majority of petrol cars to couple the crank shaft of the engine to the first-transmission shaft; the fly wheel constitutes one member, its outer face being turned into a hollow cone; the other member, a solid or male cone, is free to slide but not to rotate on the shaft to be driven, and it is pressed into contact by means of a spring; it is drawn back to disconnect the shafts by means of a pedal

which operates a lever that is in engagement with an annular groove in its boss or centre piece.

A form of coupling which is now becoming general in the motor car is the *universal* or *Hooke's joint*, or, as it is called on the Continent, the *Cardan joint*. This mechanism is on precisely the same principle as the gimbal suspension of the mariner's compass, and it allows one shaft to be somewhat inclined to the other and to sway about, which a rigid connection will not permit.

The mechanical systems of transmission and speed gearing, although comparatively simple, have certain disadvantages; they are more or less noisy and liable to breakage in consequence of the twisting and straining of the car frame, and, in the case of the variable-speed gears, the possible number of changes of speed is limited and the change demands some skill to effect without damage to the parts. Accordingly attempts have been made to replace them by hydraulic or electric systems of transmission, both of which are silent, give a continuous graduation over a wide range of speed ratios, and are not affected by the distortion of the frame. In the hydraulic system a pump on the engine shaft is employed to force water to a water motor, on the driving axle, from which a return pipe proceeds to the pump; the passage through the connecting pipes may be throttled or the water may be short circuited, to a greater or less extent, with corresponding changes in the speed imparted to the motor. This is simply an outline of the action which takes place; the carrying out of the idea in practice, as, in Hall's system, is necessarily somewhat more complex. In the electric system the pump and water motor are replaced by a dynamo and electro motor, and the speed of the latter is varied by means of a controller as in an electric car. By fitting a storage battery the engine and dynamo may be kept running at a uniform speed, and surplus power may be stored up at one time to meet increased demands at another. The dynamo may be driven directly, or by gearing, from the engine shaft, and

the motor may be mounted directly on, or be geared to, the driving axle, or separate motors may be used for each wheel, either mounted directly thereon or geared thereto. Several cars have been built with electric transmissions. The Mercedes-Lohner-Porsche, Champrobert, Jenatzy, and Krieger cars may be mentioned, and the system has been applied to an omnibus by an American, Fischer, with promising results.

The Compensating Gear

In an ordinary horse-drawn or other vehicle propelled by external means the wheels run loose on their axles and are free to rotate faster or slower as circumstances may dictate. With a wheel of the same diameter on each side it is clear that when a vehicle moves in a straight line both wheels will make a complete revolution in exactly the same time, and that while the vehicle is moving a distance equal to the circumference of the wheels. When the vehicle is moving in a curved path, as for instance in a circle, the path of the outer wheel will be longer than that of the inner, and it will accordingly require to make a greater number of revolutions in a given time than the inner wheel. The wheels being free there is no difficulty in this, and the carriage may follow any curved path without slip of the wheels.

In a motor vehicle different conditions prevail, for the power for propulsion has to be exerted through the wheels. If we are content to drive by one wheel only, and allow the other to run free the difficulty disappears, but the plan, although it has been tried, is obviously not a good one, as it would be difficult to keep a car so driven moving in a straight line. Some plan has to be devised by which the driving power may be imparted to both wheels while still allowing one wheel to run faster or slower than the other. One system which has been tried, and is in use on some electric vehicles,

for securing this end has been to drive each wheel by a separate motor, each controllable independently of the other. The plan which is in general use, however, is the ingenious device variously known as the *compensating*, *balance*, or *differential* gear.

The action of this gear may be explained very shortly. Each road wheel is mounted on a separate axle, or say rather the axle is divided in the middle, and carries near its inner ends two bevel wheels, one for each half axle and road wheel. The bevel wheels face each other, and gear with a pinion placed between them and mounted, with its axis radial to the axle, in a carrier wheel capable of rotating about the axle. The carrier wheel receives the driving power, as by means of a chain wheel secured to it, and transmits it by means of the pinion to the bevel wheels and so to the road wheels. As long as these are moving in a straight path, to cover which they require to make the same number of revolutions in a given time, the pinion revolves round the axle as if it were solid with the carrier wheel. When, however, the vehicle is constrained by the steering mechanism to move in a curved path, and the inner wheel must move slower and the outer wheel faster than before, the pinion turns on its own axis in the carrier wheel, and allows one bevel wheel to advance and the other to retire in relation to the carrier wheel. The compensating gear is, after all, not a perfect piece of mechanism for this purpose; suppose the carriage to be going straight forward, and that at one point one of the wheels arrives above a gap in the road, so that it is out of contact, it is then free to spin around without doing work; the consequence is that the pinion, instead of continuing to drive the other bevel wheel, rolls round and leaves it stationary. In practice, however, this defect is remedied by the inertia of the carriage itself, which carries the wheels onwards from such a point to level ground.

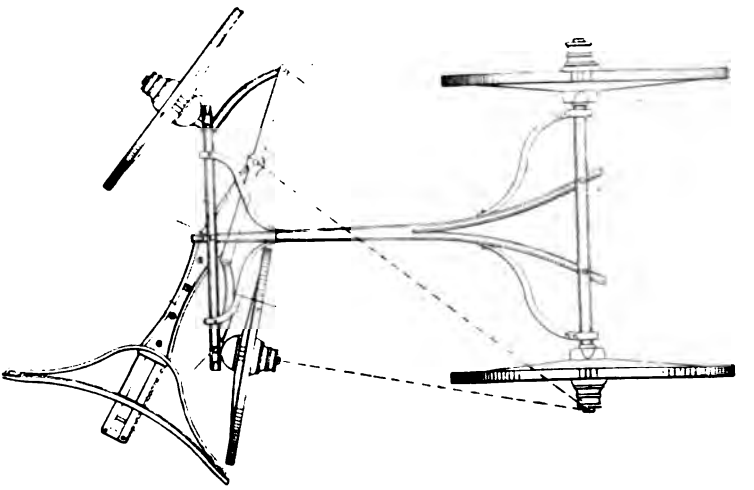
The gear described above is a bevel-wheel compensating gear; two or more pinions are usually used in order to

balance the rotating mass. The gear may be made with spur wheels.

Brakes

The importance of powerful and properly-constructed brakes in a high-speed machine cannot be over-estimated, and there is no doubt that in general the makers have bestowed a due amount of attention upon the subject. The Light Locomotives Act requires that every motor vehicle shall be fitted with two independent brakes. The usual practice is to apply a band brake to each of the rear wheels, and another to one of the transmission shafts. The band brake consists of a drum fixed to the wheel or shaft, as the case may be, and encircled for the greatest part of its circumference by a metal band lined with leather, wood, or some other material adapted to increase the friction. Normally the band stands a little distance away from the periphery of the drum; it is contracted upon it by pulling at its ends. When, as in the motor car, it is required to be able to check rotation of the drum in either direction, both ends of the band should be pulled simultaneously, and the connections with the operating handle or pedal are arranged to do this. If one end only of the band be tightened, the brake will act when the drum is rotating in the direction of the pull on the band, but not in the opposite direction. The brake on the transmission shaft is usually operated by a pedal; those on the rear wheels by a hand lever at the side of the car, and in order that each band may be tightened equally some form of equalising device must be introduced in the connections. In the Daimler car, for instance, the pull of the hand lever is exerted upon the centre of a balance beam which extends across the frame of the car and is coupled at its ends to the bands. Some makers apply the bands to the insides of hollow drums; in this case they are expanded into action, instead of being

contracted as above described. Another form of brake, sometimes used, is the block brake in which a segmental block or shoe is applied against the surface of the drum by direct pressure. As the pressure is normal to the surface, it is immaterial in which direction the drum is rotating, so these brakes act equally well in both directions. For the



ACKERMANN'S STEERING ARRANGEMENT, 1818

same pressure exerted by the hand or foot, however, they do not produce the same effect as the band form.

STEERING GEAR

Most modern motor cars have the axles of the front wheels arranged on the Ackermann principle, so called because it was patented in this country in 1818 by Rudolph Ackermann. The inventor, however, was George Lenkensperger of Munich.[1] The two front wheels are mounted on short axles, which can be turned on vertical

[1] A crude arrangement with pivoted axles for each of the front wheels was used in Du Quet's windmill carriage a hundred years before.

pivots, fixed in the ends of the front bar of the frame, by means of arms projecting from them at about right angles. The ends of the arms are connected by a link so that both wheels are turned together, and Ackermann points out that by making the link of less length than the distance between the pivots, "it will occasion that fore wheel which is on the side to which the carriage is intended to turn to have a greater degree of obliquity than the opposite wheel. This is conducive to quick turning because the axles of all the four wheels of the carriage become directed to one point"; the object of the invention being to cause the vehicle to turn within a small compass and with safety, "because the wheels do not materially alter their bearing upon the ground when they are placed in the greatest degree of obliquity." Ackermann's drawing, of course, shows the invention in connection with a horse-drawn vehicle; in the motor car one of the arms is connected up to the steering wheel or lever. Usually a hand wheel is used, and the motion is transmitted through a worm and wheel, which has the effect of preventing the wheels from reacting upon the hand.

Tyres and Wheels

The pneumatic tyre has had a most important effect in promoting the development of the motor car. Without it the speeds now looked for would be impossible. The solid rubber cushion tyre is cheaper, and is fairly effective at low speeds in preventing the transmission of shocks to the vehicle, but at high speeds it ceases to be effective in this way, and there is among others the difficulty of keeping it in place on the wheels; but even at low speeds there is no question as to the superiority of the pneumatic tyre, while, as the speed increases, it is, to say nothing of the comfort of the travellers, invaluable in preventing the transmission of

shocks and vibration to the machinery, which would otherwise be broken or shaken apart. In the past the pneumatic tyre, although recognised as indispensable for all but light and slow-running vehicles, has been a source of continual worry and vexation and of great expense. Improvements in the process of manufacture, greater care in the selection of the material and in the proportions adopted, and possibly a better knowledge of their management on the part of the users, have resulted in a far more satisfactory state of things, and tyres are now known to run for thousands of miles without trouble. There are several makes of good tyres in the market. Essentially they consist of an outer cover of thick rubber in which layers of canvas are built up and an inner tube adapted to be expanded, by air under pressure, inside the cover. Various methods are adopted for securing the cover to the wheel run; the Michelin cover, for instance, is formed with flanges which are sprung under flanges on the wheel. The wheels in use on vehicles built in Great Britain are for the most part of wood with metal centres. In France and in America the bicycle type of wheel is in favour.

HORSE-POWER

When James Watt began to apply the steam engine to take the place of horses as a motive power in mills and factories he was met at the outset by the enquiry as to how many horses his engines would replace. To determine this, he made a series of experiments to ascertain the amount of work which the most powerful horses available, such as those employed in the London breweries could accomplish when working continuously under the most favourable conditions. He found that such horses walking at the rate of two and a half miles per hour could lift a weight of 150 pounds through a vertical distance of 220 feet in a minute, or in other words 33,000 pounds one

foot high per minute. To this result he equated the power of his engines as equivalent to so many horses or of so many horses' power, and the horse-power, taken at 33,000 pounds lifted one foot high in a minute, has come into general use as a convenient unit of power. The power of an engine can be measured in two ways. We can measure the pressure exerted by the steam or other fluid upon the piston of the engine; this is effected by an instrument also devised by Watt, termed the "indicator," which records the varying pressure during a stroke of the piston by means of a curve traced on a card. The pressure, together with the area of the piston and the speed of its movement, are the factors for determining the *indicated horse-power*. Obviously a certain proportion of the power developed in the cylinder must be expended in moving the mechanism of the engine itself, so that the power available at the crank shaft which can be expended on external work is smaller to a greater or less extent depending upon the efficiency of such mechanism. To determine this power the engine is applied to expend its energy upon a dynamometer or friction brake. This apparatus can be adjusted to absorb all the power given off by the engine, and the power so absorbed may be measured and is known as the *brake horse-power*. This is the power available for doing work outside the engine, and in, say, a locomotive with single driving wheels it is the power exerted at the peripheries of the wheels for the propulsion of the machine. In the motor car, however, the friction of the gearing employed to connect the motor to the driving wheels absorbs a considerable amount of power, in many cases, no doubt, as much as fifty per cent., so that the power available for propulsion at the peripheries of the driving wheels is still further reduced from that developed in the cylinder.

The term horse-power has long ceased, in the minds of engineers, to suggest any comparison with the actual capacity of the horse; it is taken merely as a convenient

unit of work measured in foot-pounds per minute, but the introduction of the motor car, with its engines of so many horse-power, has naturally led to a comparison with horse-drawn vehicles, and it may be asked why, if two horses are sufficient to draw a carriage, with, say, two people at a certain rate of speed, two horse-power in a motor car will not do the same. Watt's allowance was a most liberal one for the average work of the strongest horse, but it must be remembered that the animal has a reserve of power which it can bring into play for short intervals to overcome a far greater resistance than it has normally to encounter, and the horse-power was based on what the animal could do throughout a day's work, not upon what it could do when exerting its full strength for a short period.

The steam engine or other motor of a certain horse-power can overcome a certain resistance continually; it may be made bigger to overcome occasional increases in the resistance encountered, but then it is rated at a bigger horse-power.

Another point to be borne in mind is, that the vehicle itself is necessarily heavier by the weight of the propelling mechanism, and that, generally, a higher speed is expected than in the case of horses.

CHAPTER XVIII

CONCLUSION

FOR all practical purposes it may be said that the sources of power available for a motor vehicle are limited to three—petrol, steam, and electricity. Each of these presents certain advantages accompanied by disadvantages, and in weighing the one against the other it is necessary to keep in view the particular purpose for which the vehicle is intended. For use in towns, the electric car presents decided attractions; it is clean, free from smell and vibration, very easy of control, and may be stopped and started at the will of the driver. On the other hand the problem of the storage battery cannot be said to have been solved in a satisfactory manner as yet, and although considerable progress has been made, the present batteries are not sufficiently durable, and they are heavy. In a storage system of any kind it is probable that the weight will always exceed that in the case of a prime mover, so that it will not be so well adapted for long-distance work, but by planning out a route in accordance with the existing facilities for charging at electric lighting stations, etc., it is possible to make a tour with an electric car.

The steam car is silent and smooth in working, possesses a great range of power, and is easily manipulated. On the other hand, stoppages are required from time to time to replenish the supplies of fuel and water. The water consumption may, it is true, be reduced by the provision of apparatus for condensing the exhaust steam, but this means extra weight, and in the majority of cases trouble in

the boiler in consequence of the oil carried from the cylinder with the steam, which remains with the water, unless another piece of apparatus is provided to separate it. For touring purposes and long-distance travelling there can be no question as to the merits of the petrol car. Such a vehicle can carry a charge of fuel sufficient for a run of 150 to 200 miles, and in the case of electric ignition, one set of batteries will last a very much longer distance, and the loss of cooling water is of trifling amount. Even for short runs the petrol car holds its own, but it does not appear so well adapted as the electric or steam cars for journeys that have to be frequently broken. The petrol engine has to be started by giving the crank shaft a few turns by hand, and it is not convenient to stop the engine and re-start it in this way in a crowded street for instance; for short stops, the engine is accordingly allowed to run disconnected from the car, and a considerable vibration is apt to be set up, and the petrol car shows itself at its worst. With the increasing use of multi-cylinder engines this difficulty is disappearing; it is possible to start and stop a four-cylinder engine on the road merely by turning on and off the electric current for ignition, so that there is no necessity to allow it to run idle if it is preferred to stop it. This and other advantages of the multi-cylinder engine are obtained, however, at the cost of increased expense and an additional number of working parts, and for many purposes the superior simplicity of the single cylinder engine is sufficient to counterbalance its defects. The petrol engine, however, suffers in comparison with the steam and electric cars, from its small range of power, necessitating the use of a variable-speed gearing, and, from the fact that it turns in one direction only, requires the provision of a reversing gear.

As to the reliability of this type of vehicle, the trials carried out in August 1902 by the Automobile Club are a sufficient demonstration. With from sixty to seventy

NAPIER FORTY HORSE-POWER RACING CAR.
The winner of the Gordon-Bennett Cup Race, 1902, with Mr F. S. Edge, the Driver, and Mr M. S. Napier, the Builder.

vehicles running day after day over courses of upwards of a hundred miles in length it was most striking to see the fewness of the marks lost on account of delays made upon the road to effect repairs or adjustments. In some cases the entire trial was passed through without the loss of a single mark in this respect.

It is somewhat difficult to balance the cost of a private motor carriage against that of horses. When a man purchases a motor car, he invariably expects to get a great deal more out of it, both in speed and in length of running than would be possible with horses, so that a comparison of any value is not possible. In this possibility of long continuous runs maintained at a high speed the petrol car seems to be striking out a line for itself, a line in which the horse does not enter into competition at all. The report of the War Office Committee on self-propelled lorries contains a note which lays considerable stress to this point.

"The Committee desire to bring to special notice the incidental demonstration afforded by these trials, of the great possibilities for staff work, and for work in connection with the command of long transport trains, of the motor car. No vehicles drawn by horses could have possibly covered the distances or kept up the speeds required; portions of the roads, sometimes miles in length, had to be traversed and re-traversed several times, and at speeds beyond the capabilities of horseflesh. Riding horses would have been knocked up to an extent necessitating large relays. The staff officer, moreover, instead of being fatigued, is always comparatively fresh at the end of the day."

The same thing is seen taking place in connection with motor wagons; not only are they displacing horses for short-distance work, but they are entering into competition with the railways for the transit of goods over distances up to forty miles, and doing so with success. It is not difficult to see why this is so. Transit by rail involves cartage, handling, loading and unloading at the terminals, and these form a very large proportion of the

total cost over distances of the extent mentioned. With the motor wagon the goods are taken direct from one point to the other without intermediate handling and without delay; for although the actual transit from station to station is effected more rapidly by rail, there is an immense loss of time at the terminals in loading and unloading, shunting, etc. This is a most important consideration in connection with the distribution, for instance, of market garden produce, and there is no doubt that the motor wagon will find a large field in this direction as it is doing in others. Already a Road Carrying Company has been established for distributing material direct from the docks at Liverpool to the various towns of Lancashire, and with every promise of a great success.

In spite of all this, and the many forecasts which have been made from time to time, the extinction of the horse as a beast of burden is not to be looked for just yet. Even if all opposition were overcome and all the horse owners in the country decided upon replacing their horses by motor cars, it would take our engineers a good many years to produce the cars, and to educate men fit to drive them, both of which are points frequently overlooked.

As a public-service vehicle the motor car is gradually making its way, and no surprise need be felt at the fact that it is doing so but slowly. The horse is likely to hold its own on the London tramways for another year or so, although electric traction has been brought to a successful issue for some years. Motor car services are, however, at work, and giving good results in various parts of the country. Stirling's Motor Carriage Company make a vehicle adapted to carry sixteen persons, including the driver and conductor; it weighs twenty-seven hundredweights, and its wheels are fitted with solid indiarubber tyres.[1] Mr

[1] This vehicle is propelled by a two-cylinder twelve-horse-power petrol engine, placed in front under the driver's seat, which transmits its motion to the axle of the rear wheels by means of a friction clutch, variable-speed gear, longitudinal coupling shaft, and bevel wheels. The extreme length is thirteen feet.

Stirling has kept an exact account of the money expended upon this car, and the working expenses taken over a run of 10,000 miles amount to a fraction over threepence per mile. During this period the sum of £1 was spent in repairs or renewals, chiefly to the car body. Nothing was spent upon tyres, and those in use have in fact run some thousand of miles since, still it has been assumed that the driving-wheel tyres were to be renewed and that those of the front wheels were half worn. The total outlay is thus made up, reckoning in pence per mile, of :—

Tyres	0·60
Petrol (at tenpence per gallon) . .	0·68
Lubrication	0·13
Repairs	0·024
Wages of driver, conductor and cleaner .	1·65
	3·084

It is to be borne in mind that in such a service the cost of the motive power is but one of a number of items in the total working expense, and it is clear that in a highly-organised and well-managed public service system, such as that of one of the great London omnibus companies, the prospects of mechanical propulsion will have to be made very alluring in order to induce the management to discard the existing system, and to embark upon a large expenditure of capital in a new direction. Beyond this the restrictions imposed by the regulations of the Local Government Board, as they stand, appear to be such as to prevent the possibility of a successful result from the commercial point of view. Briefly the case stands thus: a motor tractor or drag, with an omnibus trailing behind it, may travel at speeds not exceeding six miles an hour; a motor vehicle weighing not more than one and a half tons unladen, twelve miles an hour; under two tons, eight miles; and over two tons, five miles an hour. Now it would seem that, however well the separate tractor may suit upon open roads, it is not well

adapted for use in crowded streets, where it may from time to time be required to move backwards within narrow limits, a movement not so readily performed by a trailing vehicle. A higher speed would also be expected in a passenger vehicle. The same remark applies to motor vehicles weighing over two tons, where the maximum speed allowable is still lower, and certainly too low for an omnibus, which on one part of its course may from the necessities of other traffic have to proceed very slowly and should accordingly be allowed a higher speed in the open roads so as to bring up the average. There remains then the speed limit of eight miles an hour, with a maximum weight of two tons. The ordinary London omnibus, which by the way is a marvel of constructive skill in reference to carrying capacity in proportion to weight, weighs thirty-two hundredweights and carries twenty-eight persons, including the driver and conductor. The motor omnibus should at least accommodate as many passengers as the present vehicles; a reduction would involve increased cost per passenger in establishment charges, etc. The figures given above for Mr Stirling's carriage show that one-half the expenses were by way of wages to the driver, conductor and cleaner. The question then becomes one of fitting the motor and gearing, and adequately strengthening the vehicle itself to stand the strains imposed by the motor, within a limit of eight hundredweights, *i.e.*, the difference between the allowable weight, two tons, and the weight of the present omnibus, thirty-two hundredweights, which is difficult if not impossible.

From these considerations it is clear that the development of the public-service motor vehicle is hampered by legislative restraints. It has been shown that the same thing applies in connection with motor wagons, while the question of the speed limit for ordinary touring cars has been a matter of public discussion for some time. Failing the entire removal of all restrictions upon self-propelled vehicles weighing less than six tons, as was recommended

by a Parliamentary Committee nearly thirty years ago (*see* p. 108 *ante*), a considerable extension of the limits of weight and speed appear to be urgently needed. Of course such an extension of the legal maximum speed would not in any way absolve a driver from the responsibility for damage done by his car.

The increasing use of the highways which is the natural outcome of the development of the motor car movement will call for their general improvement throughout the country. Roads will require to be widened, straightened, levelled and bettered in regard to surface condition to meet the extension of the traffic. The dust question is already one that calls for speedy settlement. All this tends to show the desirability of a broadly-conceived scheme of roads improvement, possibly carried on under the direction of the Central Government and at the cost of the National Exchequer. In this connection it is of interest to note that the Royal Commission on Local Taxation (Final Report, 1901), reported, *inter alia*, that the maintenance of the main roads should be a national service, and that it should be paid for to a large extent from national funds.

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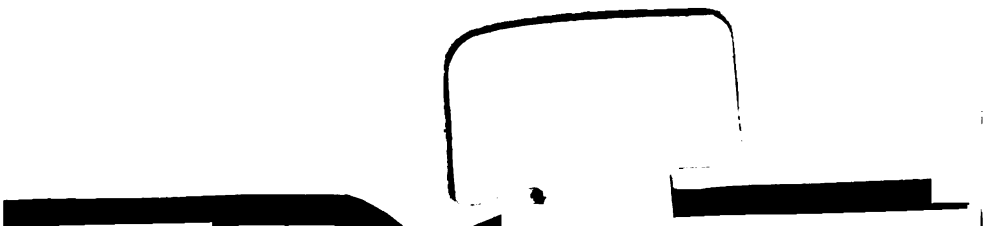

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